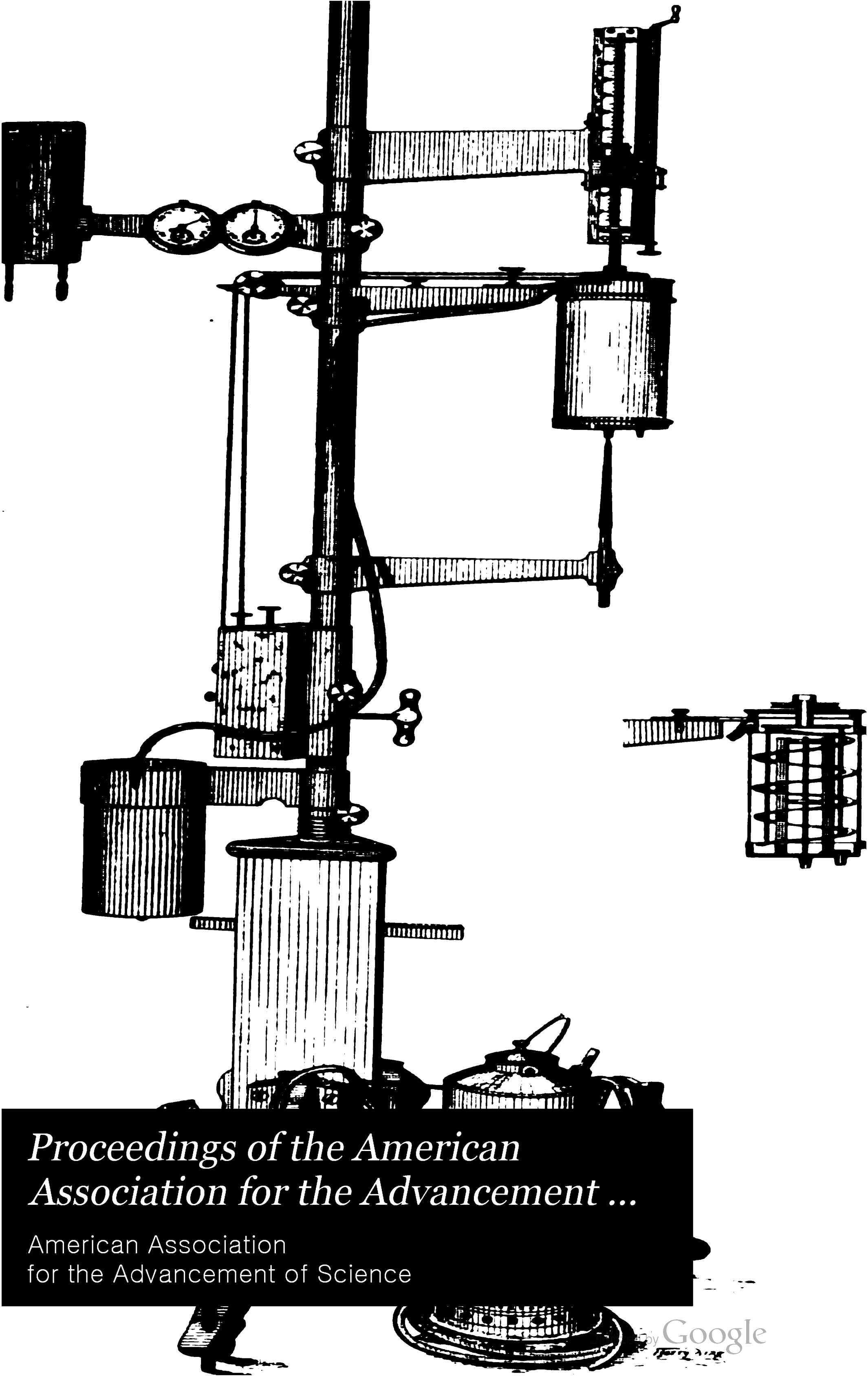

Proceedings of the American Association for the Advancement ...

American Association for the Advancement of Science

3,

PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

TWENTY-FOURTH MEETING,

HELD AT

DETROIT, MICHIGAN,

AUGUST, 1875.

SALEM:

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F. W. PUTNAM,

Permanent Secretary.

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ERRORS AND CORRECTIONS.

Part I, page 37, line 30, for "velocity" *read* distance.

Part II, page 80, line 30, *change* semicolon to comma; for "question" *read* object.

Part II, page 80, line 35, line 35, for "was" *read* is.

Part II, page 81, add the words *as seen* at end of line 26.

Part II, page 82, line 6, for "coal-measure" *read* coal-measures.

Part II, page 111, line 38, for "Cassett's" *read* Cossett's.

Part II, pages 192, 193. The use of lower case letters in the titles of publications referred to in this article, is in accordance with the changes made on proofs by the author.

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MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION OF GEOLOGISTS AND NATURALISTS.

MEETING.	DATE.	PLACE.	CHAIRMAN.	SECRETARY.	ASSIST. SEC'Y.	TREASURER.
1st	April 2, 1840,	Philadelphia,	Edward Hitchcock,*	L. C. Beck,*		
2d	April 5, 1841,	Philadelphia,	Benjamin Silliman,*	L. C. Beck,*	B. Silliman, jr., C. B. Trego, J. D. Whitney, M. B. Williams,	
3d	April 25, 1842,	Boston,	S. G. Morton,*	C. T. Jackson,		
4th	April 26, 1843,	Albany,	Henry D. Rogers,*	B. Silliman, jr.,		John Locke.*
5th	May 8, 1844,	Washington,	John Locke,*	B. Silliman, jr., O. P. Hubbard,		Douglas Houghton.*
6th	April 30, 1845,	New Haven,	Wm. B. Rogers,	B. Silliman, jr., J. Lawrence Smith,		Douglas Houghton.*
7th	Sept. 2, 1846,	New York,	C. T. Jackson,	B. Silliman, jr.,		E. C. Herrick.*
8th	Sept. 20, 1847,	Boston,	Wm. B. Rogers,†	Jeffries Wyman,*		B. Silliman, jr.

* Deceased.

†Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE-PRESIDENT.	GENERAL SECRETARY.	PERMANENT SEC'Y.	TREASURER.
1st	Sept. 20, 1848.	Philadelphia, Pa.,	W. C. Redfield,*		Walter R. Johnson,*		Jeffries Wyman.*
2d	Aug. 14, 1849.	Cambridge, Mass.,	Joseph Henry,		E. N. Horsford, 1		A. L. Elwyn.
3d	Mar. 12, 1850.	Charleston, S. C.,	A. D. Bache,* 2		L. R. Gibbs, 3		St. J. Ravenel.* 4
4th	Aug. 19, 1850.	New Haven, Conn.,	A. D. Bache,*		E. C. Herrick,*		A. L. Elwyn.
5th	May 5, 1851.	Cincinnati, Ohio,	A. D. Bache,*		W. B. Rogers, 5	S. F. Baird,	S. F. Baird. 6
6th	Aug. 19, 1851.	Albany, N. Y.,	Louis Agassiz,*		W. B. Rogers,	S. F. Baird,	A. L. Elwyn.
7th	July 28, 1853.	Cleveland, Ohio,	Benjamin Pierce,		S. St. John, 7	S. F. Baird,	A. L. Elwyn.
8th	April 26 1854.	Washington, D.C.,	J. D. Dana,		J. Lawrence Smith,	Joseph Lovering,	J. L. LeConte. 8
9th	Aug. 15. 1855.	Providence, R. I.,	John Torrey,*		Wolcott Gibbs,	Joseph Lovering,	A. L. Elwyn.
10th	Aug. 20, 1856.	Albany, N. Y.,	James Hall,		B. A. Gould,	Joseph Lovering,	A. L. Elwyn.
11th	Aug. 12, 1857.	Montreal, Canada.	Alexis Caswell, 9	Alexis Caswell,	John LeConte,	Joseph Lovering,	A. L. Elwyn.
12th	April 28, 1858.	Baltimore, Md.,	Alexis Caswell, 10	John E. Holbrook,*†	W. M. Gillespie,* 11	Joseph Lovering,	A. L. Elwyn.
13th	Aug. 3, 1859.	Springfield, Mass.,	Stephen Alexander,	Edward Hitchcock,*	William Chauvenet,*	Joseph Lovering,	A. L. Elwyn.
14th	Aug. 1. 1860.	Newport, R. I.,	Isaac Lea,	B. A. Gould,	Joseph LeConte,	Joseph Lovering,	A. L. Elwyn.
15th	Aug. 15, 1866.	Buffalo, N. Y.,	F. A. P. Barnard,	A. A. Gould,* 12	Elias Loomis, 13	Joseph Lovering,	A. L. Elwyn.†
16th	Aug. 21, 1867.	Burlington, Vt.,	J. S. Newberry,	Wolcott Gibbs,	C. S. Lyman,	Joseph Lovering,	A. L. Elwyn.†
17th	Aug. 5, 1868.	Chicago, Ill.,	B. A. Gould,	Charles Whittlesey,	Simon Newcomb, 14	Joseph Lovering,	A. L. Elwyn.†
18th	Aug. 18, 1869.	Salem, Mass.,	J. W. Foster,*	O. N. Rood,	O. C. Marsh,	F. W. Putnam, 15	A. L. Elwyn.†
19th	Aug. 17, 1870.	Troy, N. Y.,	T. S. Hunt, 16	T. S. Hunt,	F. W. Putnam, 17	Joseph Lovering,	A. L. Elwyn.†
20th	Aug. 16, 1871.	Indianapolis, Ind.,	Asa Gray,	G. F. Barker,	F. W. Putnam,	Joseph Lovering,	W. S. Vaux.
21st	Aug. 15, 1872	Dubuque, Iowa,	J. Lawrence Smith,	Alex. Winchell,	E. S. Morse,	Joseph Lovering,	W. S. Vaux.
22d	Aug. 20, 1873	Portland, Me.,	Joseph Lovering,	A. H. Worthen,†	C. A. White,	F. W. Putnam,	W. S. Vaux.
23d	Aug. 12, 1874.	Hartford, Conn.,	J. L. LeConte,	C. S. Lyman,	A. C. Hamlin,	F. W. Putnam.	W. S. Vaux.†

1. In place of Jeffries Wyman, *not present.*
2. In place of Joseph Henry, *not present.*
3. In place of E. C. Herrick, *not present.*
4. In place of A. L. Elwyn, *not present.*
5. In place of E. C. Herrick, *not present.*
6. In place of A. L. Elwyn, *not present.*
7. In place of J. D. Dana, *not present.*
8. In place of A. L. Elwyn, *not present.*
9. In place of J. W. Bailey, *deceased.*
10. In place of Jeffries Wyman, *not present.*
11. In place of Wm. Chauvenet, *not present.*
12. In place of R. W. Gibbes, *not present.*
13. In place of W. P. Trowbridge, *not present.*
14. In place of A. P. Rockwell, *called home 1st day.*
15. In place of Joseph Lovering, *in Europe.*
16. In place of Wm. Chauvenet, *too ill to be present.*
17. In place of C. F. Hartt, *in Brazil.*

* Deceased. † Not present at the meeting.

MEETINGS AND OFFICERS OF THE ASSOCIATION, CONTINUED.

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE PRESIDENT, SECTION A.	VICE PRESIDENT, SECTION B.	CHAIRMAN OF PERMANENT SUBSECTION C, CHEMISTRY.	CHAIRMAN OF PERMANENT SUBSECTION D, ANTHROPOLOGY.
24th	Aug. 11, 1875,	Detroit, Mich.,	J. E. Hilgard,	H. A. Newton,	J. W. Dawson,	S. W. Johnson,	L. H. Morgan.

PERMANENT SECRETARY.	GENERAL SECRETARY.	SECRETARY OF SECTION A.	SECRETARY OF SECTION B.	SECRETARY OF PERMANENT SUBSECTION C, CHEMISTRY.	SECRETARY OF PERMANENT SUBSECTION D, ANTHROPOLOGY.	TREASURER.
F. W. Putnam,	S. H. Scudder,	S. P. Langley, T. C. Mendenhall,	E. S. Morse,	F. W. Clarke,	F. W. Putnam,	W. S. Vaux.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

AN ACT

To Incorporate the "American Association for the Advancement of Science."

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

Section 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

Section 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

Section 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

Section 4. This act shall take effect upon its passage.

House of Representatives, March 10, 1874.
Passed to be enacted,
John E. Sanford, *Speaker*.

In Senate, March 17, 1874.
Passed to be enacted,
Geo. B. Loring, *President*.

March 19, 1874.
Approved,
W. B. Washburn.

Secretary's Department,
Boston, April 3, 1874.
A true copy, Attest:
David Pulsifer,
Deputy Secretary of the Commonwealth.

CONSTITUTION

OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS, FELLOWS, PATRONS AND HONORARY FELLOWS.

ART. 2. The Association shall consist of Members, Fellows, Patrons and Honorary Fellows.

ART. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, nomination by the Standing Committee, and election by a majority of the members and fellows present in general session.

ART. 4. Fellows shall be nominated by the Standing Committee from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members and fellows present in general session. But all persons who may be members at the time of the adoption of this constitution may become fellows by signifying their desire to this effect before the first day of August, 1875.

ART. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, to the number of ten for each section, may be elected; the nominations to be made by the Standing Committee and approved by ballot in the respective sections before election by ballot in general session. Honorary Fellows shall be entitled to all the privileges of fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected.

ART. 8. No member or fellow shall take part in the organization or business of both sections at the same meeting.

OFFICERS.

ART. 9. The Officers of the Association shall be elected by ballot in general session from the fellows and shall consist of a President, two Vice Presidents, a General Secretary, a Permanent Secretary, a Treasurer, a Secretary of Section A, and a Secretary of Section B; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The Permanent Secretary shall be elected at each fifth meeting.

ART. 10. The President, or, in his absence, one of the Vice Presidents, shall preside at all general sessions of the Association and at all meetings of the Standing Committee. It shall also be the duty of the President to give an address at a general session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be the presiding officers of Sections A and B, and of the Sectional Committees, and it shall be part of their duty to give an address, each before his respective section, at such time as the section shall determine. The Vice Presidents may request their respective sections to appoint temporary chairmen to preside over the sessions of the sections, but shall not delegate their other duties.

ART. 12. The General Secretary shall be the Secretary of all general sessions of the Association, and of all sessions of the Standing Committee, and shall keep a record of the business of these sessions. He

shall receive the records from the Secretaries of the Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting. He shall receive proposals for membership and bring them before the Standing Committee. He shall give to the Secretary of each Section the list of papers assigned to it by the Standing Committee.

ART. 18. The Permanent Secretary shall be the executive officer of the Association under the direction of the Standing Committee. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually at the first meeting of the Standing Committee, a report which shall be laid before the Association. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least four months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Standing Committee, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Standing Committee, and, at the close of each year, shall pay over to the Treasurer such unexpended funds as the Standing Committee may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Standing Committee. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Standing Committee, and may employ a clerk at such compensation as may be agreed upon by the Standing Committee.

ART. 14. The Treasurer shall invest the funds received by him in such securities as may be directed by the Standing Committee. He shall annually present to the Standing Committee an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Standing Committee, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Standing Committee.

ART. 15. The Secretaries of Sections A and B shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the secretaries of the sectional committees.

ART. 16. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Standing Committee as the President of the meeting. Vacancies in the offices of Vice President, General Secretary, Permanent Secretary and Treasurer, shall be filled by nomination of the Standing Committee and election by ballot in general session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the section.

ART. 17. The Standing Committee shall consist of the past Presidents, the President, the Vice Presidents, the four Secretaries, the Treasurer, with the above named officers of the preceding meeting, and six fellows elected by ballot after open nomination at the first general session. The members present at any regularly called meeting of the Committee, provided there are at least five, shall form a quorum for the transaction of business. The Standing Committee shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Committee shall be held in the committee room at 9 o'clock, A.M., on each day of the meeting of the Association. Special meetings of the Committee may be called at any time by the President. The Standing Committee shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Committee. The special business of the Committee shall be: to receive and assign papers to the respective sections; to examine and, if necessary, to exclude papers; to decide which papers, discussions and other proceedings shall be published, and to have the general direction of

the publications of the Association; to manage the financial affairs of the Association; to arrange the business and programmes for general sessions; to appoint general sessions for the evening; to suggest subjects for discussion, investigation or reports; to nominate members and fellows; to receive and act upon all invitations extended to the Association and report the same at a general session of the Association.

ART. 18. The Nominating Committee shall consist of the Standing Committee, and four members or fellows elected by each of the sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice Presidents and Secretaries of the Sections shall be recommended to the Nominating Committee by sub-committees consisting of the Vice Presidents and Secretaries, and the four persons elected by each section under the first clause of this article.

MEETINGS.

ART. 19. The Association shall hold public meetings annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Standing Committee may designate.

ART. 20. General Sessions shall be held at 10 o'clock, A. M., unless otherwise ordered, on every day of the meeting, Sunday excepted, and at such other times as may be appointed by the Standing Committee.

SECTIONS AND SUBSECTIONS.

ART. 21. The Association shall be divided into two Sections, namely: A (*Mathematics*, *Astronomy*, *Physics*, *Chemistry* and *Mineralogy*) and B (*Geology*, *Zoology*, *Botany* and *Anthropology*). Either Section may, at its pleasure, form temporary or permanent subsections for the reading of papers.

ART. 22. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary, and the Chairman and Secretary of the subsections, shall form its Sectional Committee. The Sectional Com-

mittees shall have power to fill vacancies in their own numbers. There shall be no sectional meeting during a general session.

Art. 23. When any Subsection organizes, it shall elect a Chairman and Secretary and report the result to the Secretary of its Section. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section. Any Permanent Subsection may elect its Chairman for the ensuing meeting.

Art. 24. No paper shall be read in any Section or Subsection until it has been placed on the programme of the day by the Sectional Committees.

Sectional Committees.

Art. 25. The Sectional Committees shall arrange and direct the business of their respective sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Standing Committee. No change shall be made in the programme for the day without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself must be returned to the Standing Committee with the reasons why it was refused.

Art. 26. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

Papers and Communications.

Art. 27. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Standing Committee to the Sectional Committee until an abstract of the paper or the paper itself has been received.

Art. 28. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

Reports of Meetings.

Art. 29. Whenever practicable, the proceedings and discussions at general sessions, sections and subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the secretaries.

Printed Proceedings.

Art. 30. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers ready for the press and forward them to the Permanent Secretary within this interval, otherwise only the abstracts or titles will appear in the printed volumes. The Standing Committee shall have power to print an abstract only of any paper. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Standing Committee. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Standing Committee. The Standing Committee shall also designate the institutions to which copies shall be distributed.

Local Committee.

Art. 31. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

Library of the Association.

Art. 32. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full

shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting, or the value of any not so returned paid to the Permanent Secretary. Not more than ten books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Standing Committee.

Admission Fee and Assessments.

Art. 33. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

Art. 34. The annual assessment for members and fellows shall be three dollars.

Art. 35. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall be exempt from all further assessments, but this payment shall not entitle him to the publications of the Association, and all money thus received shall be invested as a permanent fund, the income of which shall be used only to assist in original research.

Art. 36. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

Accounts.

Art. 37. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by two auditors appointed by the Standing Committee.

Alterations of the Constitution.

Art. 38. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in general session, after notice given at a general session of a preceding meeting of the Association.

ORDER OF PROCEEDINGS

IN

ORGANIZING A MEETING.

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1. The retiring President introduces the President elect, who takes the chair.
2. Formalities of welcome of the Association as may be arranged by the Local Committee.
3. Report of the list of papers on the register and their reference to the Sections.
4. Other reports.
5. Announcements of arrangements by the Local Committee.
6. Elections to complete the Standing Committee.
7. Election of members.
8. Election of fellows.
9. Unenumerated business.
10. Adjournment to meet in Sections.

This order, so far as applicable, to be followed in subsequent General Sessions.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.[1]

PATRON.[2]

Thompson, Mrs. Elizabeth, Stamford, Conn. (22).

LIFE MEMBERS.[3]

Elwyn, Alfred L., Philadelphia, Pa. (1).
Lyman, Benj. Smith, care Smith, Archer & Co., Yokohama, Japan (15).
Robertson, Thomas D., Rockford, Ill. (10).
Stephens, W. Hudson, Lowville, N. Y. (18).
Warner, James D., 199 Baltic St., Brooklyn, N. Y. (18).

MEMBERS.

Abbe, George W., 32 East 20th St., New York (23).
Abbot, Miss Elizabeth O., No. 10 Thomas St., Providence, R. I. (20).
Adcock, Prof. Robert J., Monmouth, Warren Co., Ill. (21).
Aikin, Prof. W. E. A., Baltimore, Md. (12).
Ainsworth, Frank B., Sup't Ind. House of Refuge, Plainfield, Ind. (20).
Albert, Augustus J., Baltimore, Md. (12).

[1] The numbers in parentheses indicate the meeting at which the member was elected. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings.

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, are exempt from the annual assessments and are entitled to the annual volume.

[3] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The money derived from Life Memberships is invested as a fund, the income of which is to be used only to aid in original research. Life Members are exempt from the annual assessment, and an additional payment of ten dollars entitles a Life Member to the annual volumes.

Allen, B. Rowland, Insurance Agent, Hartford, Conn. (23).
Allen, H. R., Indianapolis, Ind. (24).
Allen, J. M., Hartford, Conn. (22).
Allen, Stephen M., 28 State St., Boston, Mass. (23).
Allyn, Mrs. Clarence, Gale's Ferry, New London Co., Conn. (22).
Andrews, Prof. E. B., Lancaster, Ohio (7).
Andrews, Dr. Edmund, 6 Sixteenth St., Chicago, Ill. (22).
Armsby, Henry P., Millbury, Mass. (23).
Armstrong, Rev. John W., D.D., State Normal School, Fredonia, N. Y. (24).
Arthur, J. C., Charles City, Iowa (21).
Atwater, Samuel T., 166 Washington St., Chicago, Ill. (17).
Atwater, Mrs. Samuel T., 166 Washington St., Chicago, Ill. (17).
Austin, Mrs. E. P., Cambridge, Mass. (24).

Babbitt, Henry S., M. D., Columbus, Ohio (23).
Babcock, Prof. Samuel S., Mt. Clemens, Macomb Co., Mich. (24).
Baird, Lyman, 90 La Salle St., Chicago, Ill. (17).
Baker, Prof. Arthur L., Lafayette College, Easton, Pa. (24).
Baker, Prof. T. R., Millersville, Lancaster Co., Penn. (22).
Balch, David M., Salem, Mass. (22).
Barnard, Jas. M., Boston, Mass. (18).
Barnard, Wm. Stebbins, Canton, Ill. (24).
Bartlett, Frank L., Hanover, Me. (22).
Bassett, George W., M. D., Vandalia, Ill. (20).
Bassnett, Thomas, Jacksonville, Fla. (8).
Bassnett, Mrs. Thomas, Jacksonville, Fla. (24).
Batterson, J. G., Hartford, Conn. (23).
Beach, Charles M., Merchant, Hartford, Conn. (23).
Beach, J. Watson, Merchant, Hartford, Conn. (23).
Beach, William H., Beloit, Wis. (21).
Beal, Prof. Wm. James, Agricultural College, Lansing, Mich. (24).
Becker, Dr. Alexander R., 265 Benefit St., Providence, R. I. (22).
Bell, James D., Office of Daily Graphic, New York (20).
Bell, John J., Exeter, N. H. (22).
Benjamin, E. B., 10 Barclay St., New York (19).
Bessey, Prof. C. E., Agricultural College, Ames, Iowa (21).
Bickmore, Prof. Albert S., Am. Mus. of Nat. Hist., Central Park, N. Y. (17).
Bill, Charles, Springfield, Mass. (17).
Blake, Clarence J., M. D., Hotel Berkeley, Boston, Mass. (24).
Blake, Dr. Mary J. Safford, 16 Boylston Place, Boston, Mass. (21).
Blake, W. P., Geologist, New Haven, Conn. (2).
Blakeslee, B. F., Stock Broker, Hartford, Conn. (23).
Blatchford, Eliphalet W., 70 North Clinton St., Chicago, Ill. (17).
Bliss, Porter C., Journalist (18).
Blois, John T., Jonesville, Hillsdale Co., Mich. (24).
Boadle, John, Haddonfield, N. J. (20).
Bolles, Rev. E. C., Salem, Mass. (17).

Bontecou, Dr. R. B., Troy, N. Y. (19).
Bowen, Lemuel W., care D. M. Ferry & Co., 203 Woodward Ave., Detroit, Mich. (24).
Bowen, Silas T., Indianapolis, Ind. (20).
Boynton, Miss Susan P., Box 150, Lynn, Mass. (19).
Breneman, A. A., Lancaster, Penn. (20).
Brevoort, J. Carson, Brooklyn, N. Y. (1).
Briggs, Albert D., 7 Fort Block, Springfield, Mass. (18).
Briggs, S. A., Box 545, Chicago, Ill. (17).
Brigham, Rev. Charles H., Ann Arbor, Mich. (17).
Bristol, Eugene S., New Haven, Conn. (17).
Broomall, Hon. John M., Media, Delaware Co., Pa. (23).
Bryan, Oliver N., Accokeek P. O., Prince George's Co., Md. (18).
Buckhout, W. A., State College, Centre Co., Pa. (20).
Burbank, L. S., Woburn, Mass. (18).
Burgess, Edward, Sec'y Nat. Hist. Society, Boston, Mass. (22).
Bush, Stephen, Waterford, N. Y. (19).

Cadman, Charles C., Merchants' & Manufacturers' Bank, Detroit, Mich. (24).
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22).
Canby, William M., 1101 Delaware Ave., Wilmington, Del. (17).
Capen, Miss Bessie T., Wellesley College, Wellesley, Mass. (23).
Carpenter, Prof. G. C., Simpson Centenary College, Indianola, Iowa (22).
Carpenter, Lieut. W. L., 9th U. S. Infantry, Fort Lyon, Colorado (24).
Carrington, Col. Henry B., U. S. A., Prof. in Wabash College, Crawfordsville, Ind. (20).
Case, L. B., Richmond, Indiana (17).
Cattell, William C., President Lafayette College, Easton, Penn. (15).
Chadeayne, Miss E., 85 Grand St., Jersey City, N. J. (22).
Chamberlin, T. C., Beloit College, Beloit, Wis. (21).
Chanute, O., care Erie Railway, New York (17).
Chapman, F. M., 269 Lincoln Ave., Chicago, Ill. (17).
Chase, Prof. Pliny E., Haverford College, Haverford, Penn. (18).
Chase, R. Stuart, 16 Merrimack St., Haverhill, Mass. (18).
Chase, Theodore R., Detroit, Mich. (24).
Chesbrough, E. S., Chicago, Ill. (2).
Chickering, Prof. J. W., jr., Deaf Mute College, Washington, D. C. (22).
Coffinberry, W. L., Grand Rapids, Mich. (20).
Cogswell, Dr. George, Bradford, Mass. (18).
Collins, Prof. Alonzo, Cornell College, Mount Vernon, Iowa (21).
Colton, G. Woolworth, 172 William St., New York (22).
Comstock, Theodore B., Ass't Prof. Geol. Dep't, Cornell University, Ithaca, N. Y. (24).
Connerly, Prof. D. C. B., Principal Huntsville High School, Huntsville, Ala. (23).
Conser, Prof. E. P., Sand Spring, Iowa (21).
Cook, Prof. A. J., Agricultural College, Lansing, Mich. (24).

Cooke, Caleb, Peabody Academy of Science, Salem, Mass. (18).
Cooley, Prof. Le Roy C., N. Y. State Normal School, Albany, N. Y. (19).
Copes, Dr. Joseph S., care Copes & Ogden, New Orleans, La. (11).
Corwin, Richard W., University Museum, Ann Arbor, Mich. (24).
Coxe, Eckley B., Drifton, Jeddo P. O., Luzerne Co., Pa. (23).
Crawford, Dr. John S., Galena, Ill. (21).
Crehore, John D., Cleveland, Ohio (24).
Crosby, M. S., Pres't Waterbury Scientific Soc., Waterbury, Conn. (23).
Cross, Japheth, Adrian, Mich. (24).
Cummings, John, Woburn, Mass. (18).
Curtis, Rev. Dr. W. S., Rockford, Ill. (21).
Cusick, Cornelius C., Lieut. 22nd Reg. Infantry, U. S. A., Washington, D. C. (24).
Cutter, John D., 1208 Pacific St., Brooklyn, L. I. (23).

Davis, George T., Portland, Me. (23).
Davis, James (1).
Dawson, Mrs. Margaret Y., Montreal, Canada (24).
DeCamp, Dr. William H., Grand Rapids, Mich. (21).
Delano, Joseph C., New Bedford, Mass. (5).
Derby, O. A., Ithaca, N. Y. (23).
Devereux, J. H., President C. C. C. & I. R. R., Cleveland, Ohio (18).
Dickinson, Rev. John, 167 Tompkins Avenue, Brooklyn, L. I. (23).
Dixwell, Epes S., Cambridge, Mass. (1).
Dodd, C. M., Williamstown, Mass. (19).
Doggett, Mrs. Kate N., Chicago, Ill. (17).
Doggett, Wm. E., Chicago, Ill. (17).
Dolbear, A. Emerson, Bethany, West Va. (20).
Doughty, John W., Newburgh, N. Y. (19).
Douglas, Prof. Samuel T., Ann Arbor, Mich. (24).
Douglas, Prof. Silas H., Ann Arbor, Mich. (24).
Downer, Henry E., 103 Woodward Ave., Detroit, Mich. (21).
Drowne, Charles, care William L. Drowne, Esq., Canaan Four Corners, New York (6).
Drummond, Josiah H., Portland, Me. (22).
Dudley, Charles B., Altoona, Pa. (23).
Dyer, Clarence, Lawrence, Mass. (22).
Dyer, Elisha, 26 Westminster St., Providence, R. I. (9).

Eaton, Prof. James H., Beloit College, Beloit, Wis. (17).
Edgar, Col. George M., Principal of Edgar Institute, Paris, Ky. (20).
Edwards, A. Mead, M. D., 120 Belleville Ave., Newark, N. J. (18).
Elliott, Arthur H., Highlands, N. Y. (23).
Emerson, Prof. Benjamin K., Amherst, Mass. (19).
Endlech, Dr. Frederic N., Smithsonian Institution, Washington, D. C. (22).
Ennis, Jacob, Principal Scientific Inst., Philadelphia, Penn. (19).
Everts, Miss M. M., care Rev. W. W. Everts, D. D., Chicago, Ill. (22).

Faries, R. J., Wauwatosa, Wis. (21).
Farquharson, Dr. Robert James, Davenport, Iowa (24).
Fellowes, R. S., New Haven, Conn. (18).
Fernald, Prof. Charles H., State Agricultural College, Orono, Me. (22).
Fernald, Prof. M. C., State Agricultural College, Orono, Me. (22).
Feuchtwanger, Dr. Lewis, 180 Fulton St., New York (11).
Ficklin, Prof. Joseph, University of Missouri, Columbia, Mo. (20).
Fisher, Prof. Davenport, from June 1 to Oct. 1, 642 Marshall St., Milwaukee, Wis.; rest of the year, Annapolis, Md. (17).
Fisk, Rev. Dr. Richmond, jr., Grand Rapids, Mich. (19).
Fletcher. Ingram, care Fletcher & Sharpe, Indianapolis, Ind. (20).
Fletcher, Dr. Wm. B., Indianapolis, Ind. (20).
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Dean, George, W., U. S. Coast Survey, Fall River, Mass. (15).
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Dinwiddie, Robert, 113 Water St., New York (1).
Dodge, Charles R., Washington, D. C. (22).
Dutton, Capt. Clarence E., U. S. Ordnance Dep't, Washington, D. C. (23).
Dwyer, Dr. John, Hartford, Conn. (23).

Eaton, Prof. D. G., Packer Institute, Brooklyn, N. Y. (19).
Eddy, Prof. H. T., University of Cincinnati, Cincinnati, Ohio (24).
Edwards, Thomas C., P. O. Box A E, Vineland, N. J. (21).
Elmbeck, Wm., U. S. C. S., P. O. Box 1588, San Francisco, Cal. (17).
Elliott, Ezekiel B., Statistical Bureau, Washington, D. C. (10).
Elmore, Samuel E., Pres't Conn. River Banking Co., Hartford, Conn. (23).
Elsberg, Louis, M. D., 8 West 28th St., New York (23).
Emerson, Prof. C. F., Dartmouth College, Hanover, N. H. (22).
Emerson, George B., LL.D., 8 Pemberton Sq., Boston, Mass. (1).

Emerton, James H., Salem, Mass. (18).
Engelmann, Dr. George, St. Louis, Mo. (1).
Ernst, Rev. Carl W., P. O. Box 671, Providence, R. I. (23).
Eustis, Prof. Henry L., Cambridge, Mass. (2).
Evans, Asher B., Principal Union School, Lockport, N. Y. (19).

Fairbanks, Prof. Henry, St. Johnsbury, Vt. (14).
Farlow, Dr. W. G., Cambridge, Mass. (20).
Farmer, Moses G., Salem. Mass. (9).
Ferrel, William, U. S. Coast Survey Office, Washington, D. C. (11).
Fitch, Edmund H., Secretary Toledo Soc. Nat. Sciences, Toledo, O. (23).
Fitch, Edward H., Ashtabula, Ohio (11).
Fitch, O. H., Ashtabula, Ohio (7).
Foote, Dr. A. E., 3725 Lancaster Avenue, Philadelphia, Pa. (21).

Gardiner, Rev. Frederic, D. D., Middletown, Conn. (23).
Garman, S. W., Museum Comp. Zoology, Cambridge, Mass. (20).
Genth, Prof. F. A., University of Pennsylvania, Philadelphia, Penn. (24).
Gilbert, G. K., 99 Arcade, Rochester, N. Y. (18).
Gill, Prof. Theodore, Smithsonian Institution, Washington, D. C. (17).
Gillman, Henry, 80 Elizabeth St., West, Detroit, Mich. (24).
Gilman, Daniel C., President of the John Hopkins University, Baltimore, Md. (10).
Gleason, F. L., Manufacturer Iron and Steel, Hartford, Conn. (23).
Goessman, Prof. C. A., State Agricultural College, Amherst, Mass. (18).
Goodale, Prof. G. L., Botanic Gardens, Cambridge, Mass. (18).
Goode, Prof. George Brown, Middletown, Conn. (22).
Grant, Mrs. Mary J., Brookfield, Conn. (23).
Gray, Prof. Asa, Botanic Gardens, Cambridge, Mass. (1).
Green, Dr. Traill, Easton, Pa. (1).
Grimes, J. Stanley, Evanston, Ill. (17).
Grinnan, A. G., Orange Court House, Va. (7).
Grote, Aug. R., Secretary Buffalo Soc. Nat. History, Buffalo, N. Y. (22).
Guyot, Prof. Arnold, Princeton, N. J. (1).

Hadley, George, 1355 Main St., Buffalo, N. Y. (6).
Hagen, Dr. Hermann A., Mus. Comp. Zool., Cambridge, Mass. (17).
Haldeman, Prof. S. S., Chickies, Pa. (1).
Hale, Dr. William H., Albany, N. Y. (19).
Hall, Prof. James, Albany, N. Y. (1).
Hambly, John B., Portsmouth, R. I. (18).
Hamlin, Dr. A. C., Bangor, Me. (10).
Harrington, Prof. Mark W., Ann Arbor, Mich. (22).
Harrison, Dr. B. F. Wallingford, Conn. (11).
Hartshorne, Prof. Henry, Haverford College, Montgomery Co., Penn. (12).
Hasbrouck, Prof. Isaac E., Rutger's College, New Brunswick, N. J. (23).

Hawes, George W., New Haven, Conn. (23).
Hawley, C. T., Spring Street Avenue, Milwaukee, Wis. (20).
Hedrick, B. S., Examiner U. S. Patent Office, Washington, D. C. (19).
Henry, Prof. Joseph, Secretary Smithsonian Institution, Washington, D. C. (1).
Hilgard, Prof. Eugene W., University of California, Berkeley, Cal. (1).
Hilgard, Prof. Julius E., U. S. Coast Survey, Washington, D. C. (4).
Hill, George W., Mathematician, Nyack Turnpike, N. Y. (23).
Hill, Rev. Dr. Thomas, 109 State St., Portland, Me. (3).
Hinrichs, Prof. Gustavus, State University, Iowa City, Iowa (17).
Hitchcock, Prof. Charles H., Hanover, N. H. (11).
Holden, Prof. Edward S., Naval Observatory, Washington, D. C. (23).
Hosford, Charles E., Terre Haute, Ind. (20).
Hough, Franklin B., Lowville, N. Y. (4).
Hough, G. W., Albany, N. Y. (15):
Howe, Elliott C., M. D., Yonkers, N. Y. (19).
Hoy, Philo R., M. D., Racine, Wis. (17).
Hunt, George, Providence, R. I. (9).
Hunt, Dr. T. Sterry, St. James Hotel, Boston, Mass. (1).
Huntington, Prof. J. H., Hanover, N. H. (19).
Hyatt, Prof. Alpheus, Natural History Society, Boston, Mass. (18).
Hyatt, James, Stanfordville, Dutchess Co., N. Y. (10).

Jenks, Elisha T., Middleborough, Mass. (22).
Jenks, Prof. J. W. P., Middleborough, Mass. (2).
Johnson, S. W., Sheffield Scientific School, New Haven, Conn. (22).
Johnston, Prof. John, Middletown, Conn. (1).
Julien, Alexis A., School of Mines, Columbia College, New York (24).

Kellogg, Justin, 259 River St., Troy, N. Y. (19).
Kerr, Prof. W. C., Raleigh, N. C. (10).
King, Robert, M. D., Kalamazoo, Mich. (21).
Kirkwood, Prof. Daniel, Bloomington, Ind. (7).

Lambert, Thomas R., Charlestown, Mass. (18).
Lambert, Dr. T. S., New York (21).
Langley, Prof. John W., University of Michigan, Ann Arbor, Mich. (23).
Langley, Prof. S. P., Director of Observatory, Allegheny, Pa. (18).
Lattimore, Prof. S. A., University of Rochester, Rochester, N. Y. (15).
Laws, Samuel S., (23).
Lea, Dr. Isaac, 1622 Locust St., Philadelphia, Penn. (1).
LeConte, Dr. John L., 1625 Spruce St., Philadelphia, Pa. (1).
Leeds, Prof. Albert R., Stevens Institute, Hoboken, N. J. (23).
Leonard, N. R., State University, Iowa City, Iowa (21).
Lesley, Prof. J. Peter, State Geol. of Pa., 1008 Clinton St., Phil., Pa. (2).
Levette, Gilbert M., Geologist, Indianapolis, Ind. (23).

Lindsley, Dr. J. B., Nashville, Tenn. (1).
Lintner, J. A., N. Y. State Museum of Nat. Hist., Albany, N. Y. (22).
Little, Prof. George, State Geologist of Georgia, Atlanta, Ga. (15).
Little, W. C., Albany, N. Y. (22).
Lockwood, Rev. Samuel, Freehold, N. J. (18).
Loomis, Prof. Elias, New Haven, Conn. (1).
Loughridge, Prof. R. H., Ass't State Geologist, Atlanta, Ga. (21).
Lovering, Prof. Joseph, Cambridge, Mass. (2).
Lupton, Prof. N. T., Vanderbilt Univ., Nashville, Tenn. (17).
Lyman, Prof. Chester S., New Haven, Conn. (14).
Lyman, Col. Theodore, Brookline, Mass. (23).
Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18).

Malone, David R., M.D., Edinburg, Ind. (20).
Mann, B. Pickman, 19 Follen St., Cambridge, Mass. (22).
Marcy, Prof. Oliver, Evanston, Ill. (10).
Marsh, Prof. O. C., Yale College, New Haven, Conn. (15).
Mayer, Prof. Alfred M., Stevens Inst. Technology, Hoboken, N. J. (19).
McClintock, Frank, West Union, Iowa (22).
McMurtrie, William, Dep't Agriculture, Washington, D. C. (22).
McRae, Hamilton S., Sup't of Schools, Muncie, Ind. (20).
Meehan, Thomas, Germantown, Penn. (17).
Meigs, Dr. James Aitken, 1408 Spruce St., Philadelphia, Pa. (12).
Mendenhall, Prof. T. C., Agric. and Mechanical Coll., Columbus, Ohio (20).
Mitchell, Miss Maria, Vassar College, Poughkeepsie, N. Y. (4).
Moore, Prof. James W., M. D., Lafayette College, Easton, Pa. (22).
Morgan, Hon. L. H., Rochester, N. Y. (11).
Morris, Rev. John G., Baltimore, Md. (12).
Morse, Prof. Edward S., Salem, Mass. (18).
Morton, Henry, Stevens Institute Technology, Hoboken, N. J. (18).
Munroe, Prof. Chas. E., U. S. Naval Academy, Annapolis, Md. (22).

Nason, Prof. H. B., Rensselaer Polytechnic Inst., Troy, N. Y. (13).
Nelson, The Rev. Dr. Cleland K., Annapolis, Md. (12).
Newberry, Prof. J. S., Cleveland, Ohio, and Columbia Coll., New York (5).
Newcomb, Prof. Simon, U. S. Naval Observatory, Washington, D. C. (13).
Newton, Hubert A., New Haven, Conn. (6).
Nichols, Prof. W. R., Mass. Inst. Technology, Boston, Mass. (18).
Niles, Prof. W. H., Cambridge, Mass. (16).
Norton, Prof. W. A., New Haven, Conn. (6).

Oliver, Miss Mary E., Cascadilla Hotel, Ithaca, N. Y. (20).
Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19).
Osborne, John W., Washington, D. C. (22).

Osten Sacken, Baron R., Mus. Comp. Zoology, Cambridge, Mass. (10).
Owen, Dr. Richard, Ind. State University, Bloomington, Ind. (20).

Packard, Dr. A. S., jr., Director Peabody Acad. Science, Salem, Mass. (16).
Paine, Cyrus F., Rochester, N. Y. (12).
Paine, Nathaniel, Worcester, Mass. (18).
Palfray, Hon. Charles W., Salem, Mass. (21).
Parkhurst, Henry M., Law Stenographer, 33 Park Row, New York (23).
Peckham, S. F., University of Minnesota, Minneapolis, Minn. (18).
Pedrick, Wm. R., Lawrence, Mass. (22).
Peirce, B. O., 413 Broadway, Cambridge, Mass. (18).
Perkins, Maurice, Schenectady, N. Y. (15).
Pettee, Prof. William H., Ann Arbor, Mich. (24).
Phippen, Geo. D., Salem, Mass. (18).
Pickering, Prof. Edward C., Boston, Mass. (18).
Pourtales, L. F., Keeper Museum Comp. Zoology, Cambridge, Mass. (1).
Powell, Major J. W., 910 M St., Washington, D. C. (23).
Prescott, Prof. Albert B., Ann Arbor, Mich. (23).
Prime, Prof. Frederick, Jr., Easton, Pa. (24).
Pumpelly, Prof. Raphael, Owego, Tioga County, N. Y. (17).
Putnam, F. W., Curator Peabody Museum Archæology and Ethnology, Cambridge, Mass. Address as Permanent Sec'y A. A. A. S., Salem, Mass. (10)
Pynchon, Rev. Thomas R., Pres't of Trinity College, Hartford, Conn. (23).

Quimby, Prof. E. T., Hanover, N. H. (22).
Quincy, Edmund, jr., 160 South Market St., Boston, Mass. (11).

Raymond, R. W., Box 4404, New York (15).
Redfield, John H., care A. Whitney & Sons, Philadelphia, Pa. (1).
Remsen, Prof. Ira, Williams College, Williamstown, Mass. (22).
Rice, Prof. Wm. North, Middletown, Conn. (18).
Richards, Prof. Robert H., Mass. Inst. Tech., Boston, Mass. (22).
Riley, Prof. C. V., St. Louis, Mo. (17).
Rockwell, Joseph P., Creston, Iowa (17).
Rockwood, Prof. Charles G., Jr., Rutger's Coll., New Brunswick, N. J. (20).
Roepper, Charles W., Bethlehem, Pa. (23).
Rogers, Fairman, 202 West Rittenhouse Sq., Philadelphia, Pa. (11).
Rogers, Prof. Robert E., University of Penn., Philadelphia, Pa. (18).
Rogers, W. A., Ass't Harvard Coll. Observatory, Cambridge, Mass. (15).
Rogers, Prof. William B., 117 Marlboro St , Boston, Mass. (1).
Rood, Prof. O. N., New York (14).
Roosevelt, Clinton, No. 11 Wall St., New York (11).
Ross, Dr. Alexander M., Toronto, Ontario (21).
Runkle, Prof. J. D., President Institute of Technology, Boston, Mass. (2).
Rutherford, Lewis M., 175 Second Ave., New York (13).

Sadtler, Prof. Samuel P., University of Penn., Philadelphia, Pa. (22).
Safford, Dr. James M., Nashville, Tenn. (6).
Saunders, William, London, Ontario, Canada (17).
Saville, Dr. John J., Sioux City, Iowa. (22).
Schott, Charles A., Coast Survey Office, Washington, D. C. (8).
Scudder, Samuel H., Cambridge, Mass. (13).
Seaman, Wm. H., Microscopist, Agric. Dep't, Washington, D. C. (23).
Shaler, Prof. N. S., Newport, Ky., and Cambridge, Mass. (19).
Sias, Solomon, Schoharie C. H., Schoharie Co., N. Y. (10).
Sill, Hon. Elisha N., Cuyahoga Falls, Ohio (6).
Silliman, Prof. Benjamin, Yale Coll., New Haven, Conn. (1).
Silliman, Prof. Justus M., Easton, Pa. (19).
Smith, Dr. J. Lawrence, Louisville, Ky. (1).
Smith, S. I., New Haven, Conn. (18).
Snell, Prof. Ebenezer S., Amherst, Mass. (2).
Spencer, John W., Teacher and Geologist, Paxton, Ind. (20).
Stanard, Benjamin A., Cleveland, Ohio (6).
Stearns, Henry P., M. D., Hartford, Conn. (23).
Stearns, R. E. C., Oakland, Cal. (18).
Steiner, Dr. Lewis H., Frederick City, Md. (7).
Stephens, W. Hudson, Lowville, N. Y. (18).
Stetson, Thomas D., Solicitor of Patents, 155 E. 71st St., New York (23).
Stockwell, John N., 579 Case Ave., Cleveland, Ohio (18).
Stone, Mrs. Leander, 1571 Indiana Ave., Chicago, Ill. (22).
Storrs, Henry E., Jacksonville, Ill. (20).
Stuart, Prof. A. P. S., Lincoln, Nebraska. (21).
Swallow, Prof. G. C., Columbia, Missouri. (10).

Tappan, Eli T., Pres't of Kenyon College, Gambier, Ohio (20).
Terry, Prof. Nathaniel M., U. S. Naval Academy, Annapolis, Md. (23).
Thompson, Aaron R., 36 Pine St., New York (1).
Thurston, Prof. Robert H., Stevens Inst., Hoboken, N. J. (23).
Toner, Joseph M., M. D., 615 Louisiana Ave., Washington, D. C. (23).
Trowbridge, Prof. W. P., New Haven, Conn. (10).
Turnbull, Laurence, M. D., 1208 Spruce St., Philadelphia, Pa. (10).
Tuttle, Prof. Albert H., Columbus, Ohio (17).

Uhler, Philip R., Baltimore, Md. (19).

Van der Weyde, Dr. P. H., New York (17).
Van Vleck, Prof. John M., Middletown, Conn. (23).
Vaux, William S., 1702 Arch St., Philadelphia, Penn. (1).
Verrill, Prof. A. E., Yale College, New Haven, Conn. (16).
Vose, Prof. George L., Bowdoin College, Brunswick, Me. (15).

Wadsworth, M. Edward, Instructor in Mathematics and Mineralogy, Harvard University, Cambridge, Mass. (23).

Walker, Prof. Joseph B., care Bank of Kentucky, Louisville, Ky. (20).
Walker, Prof. J. R., Napoleon Ave., cor. Coliseum St., New Orleans, La. (19).
Waller, Elwyn, School of Mines, Columbia Coll., New York (23).
Walling, H. F., 102 Chauncy St., Boston, Mass. (16).
Ward, Prof. Henry A., Rochester, N. Y. (18).
Ward, Henry D. A., Meteorologist, Middletown, Conn. (23).
Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17).
Warner, H. C., West Union, Iowa. (21).
Warner, James D., 199 Baltic St., Brooklyn, N. Y. (18).
Warren, Gen. G. K., U.S.A., Engineer's Office, Newport, R. I. (12).
Warren, Prof. S. Edward, Institute of Technology, Boston, Mass. (17).
Watson, Sereno, Botanic Gardens, Cambridge, Mass. (22).
Webster, Prof. Nathan B., Principal Webster Inst., Norfolk, Va. (7).
Wells, Daniel H., Rocky Hill, Conn. (18).
Westcott, O. S., High School, Chicago, Ill. (21).
Wheatland, Dr. Henry, President Essex Institute, Salem, Mass. (1).
Wheatley, Charles M., Phœnixville, Penn. (1).
Wheildon, W. W., Concord, Mass. (13).
White, Prof. C. A., P. O. Box 806, Washington, D. C. (17).
Whitfield, R. P., 169 Elm St., Albany, N. Y. (18).
Whitney, Solon F., Watertown, Mass. (20).
Whittlesey, Col. Charles, Cleveland, Ohio (1).
Wilber, G. M., Pine Plains, N. Y. (19).
Wilbur, A. B., Port Jervis, Orange Co., N. Y. (23).
Wilder, Dr. Burt G., Cornell University, Ithaca, N. Y. (22).
Wiley, Prof. Harvey W., Purdue University, La Fayette, Ind. (21).
Williams, Charles H., M. D., 15 Arlington St., Boston, Mass. (22).
Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11).
Winchell, Prof. Alex., Syracuse, N. Y. (3)
Winchell, Prof. N. H., Univ. of Minnesota, Minneapolis, Minn. (19).
Witter, F. M., Muscatine, Iowa (21).
Woodworth, Dr. John M., U. S. Marine Hospital Service, Washington, D. C. (17).
Worthen, A. H., Springfield, Ill. (5).
Wright, Prof. Arthur W., Yale College, New Haven, Conn. (14).
Würtele, Rev. Louis C., Acton Vale, Province of Quebec, Canada East (11).
Wyckoff, Wm. C., Tribune Office, New York (20).
Wylie, Prof. Theophilus A., Indiana University, Bloomington, Ind. (20).

Yarrow, Dr. H. C., Box 555, Centennial P. O. West Philadelphia, Pa. (23).
Youmans, Prof. Edward L., New York (6).
Young, Prof. Charles A., Dartmouth College, Hanover, N. H. (18).

[333 Fellows.]

Total number of Members and Fellows, 807.

MEMBERS ELECTED

AT

DETROIT MEETING.

Ninety-five members were elected at the Detroit Meeting. Of these seventy-nine have paid the admission fee and assessment for the meeting, and their names have been incorporated in the list of Members. The following have not yet replied to the notifications sent to them:

Amend, Bernard G., 205 Third Ave., New York.
Anderson, John, Pres't State Agricultural College, Manhattan, Kansas.
Ballantine, Prof. Wm. G., Ripon College, Ripon, Wisconsin.
Cameron, John G. M., 87 Seventh Ave., New York.
Cross, Jude, Livermore, Almeda Co., Cal.
Fraser, James, Windsor, Ontario.
Harding, Prof. H. Wilson, Lehigh University, Bethlehem, Pa.
Hastings, Walter, Commonwealth Ave., Boston, Mass.
Hodges, R. C., Detroit, Mich.
Love, Edward G., East Saginaw, Mich.
Minns, Geo. Washington, Concord, Mass.
Stallo, Judge J. B., Cincinnati, Ohio.
Stidham, Rev. J. F., Columbus, Ohio.
Wheaton, John M., M.D., Columbus, Ohio.
Williams, Frederick Harrison, Orange, New Jersey.

DECEASED MEMBERS.

[Information respecting omissions in this list, and the date of birth and of decease of any of the former members, is requested by the Permanent Secretary.]

Abert, J. J., Washington, D. C. (1).
Adams, C. B., Amherst, Mass. (1).
Adams, Edwin F., Charlestown, Mass. (18).
Agassiz, Louis, Cambridge, Mass. (1).
Ainsworth, J. G., Barry, Mass. (14).
Allston, R. F. W., Georgetown, S. C. (3).
Anthony, Charles H., Albany, N. Y. (6).
Ames, N. P., Springfield, Mass. (1).
Appleton, Nathan, Boston, Mass. (1).

Bache, Alexander D., Washington, D. C. (1).
Bache, Franklin, Philadelphia, Pa. (1).
Bailey, J. W., West Point, N. Y. (1).
Barrett, Moses, Milwaukee, Wis. (21).
Beck, C. F., Philadelphia, Penn. (1).
Beck, Lewis C., New Brunswick, N. J. (1).
Beck, T. Romeyn, Albany, N. Y. (1).
Benedict, G. W., Burlington, Vt. (16).
Binney, Amos, Boston, Mass. (1).
Binney, John, Boston, Mass. (3).
Blanding, William, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19).
Bomford, George, Washington, D. C. (1).
Bradley, Leverette, Jersey City, N. J. (15).
Braithwaite, Jos., Chambly, C. W. (11).
Brown, Andrew, Natchez, Miss. (1).
Burnap, G. W., Baltimore, Md. (12).
Burnett, Waldo I., Boston, Mass. (1).
Butler, Thomas B., Norwalk, Conn. (10).

Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).
Case, Leonard, Cleveland, Ohio (15).
Case, William, Cleveland, Ohio (6).
Chapman, N., Philadelphia, Pa. (1).
Chase, S., Dartmouth, N. H. (2).
Chauvenet, William, St. Louis, Mo. (1).
Clapp, Asahel, New Albany, Ind. (1).
Clark, H. J., Cambridge, Mass. (13).
Clark, Joseph, Cincinnati, Ohio (5).
Clarke, A. B., Holyoke, Mass. (13).
Cleaveland, C. H., Cincinnati, Ohio (9).
Cleveland, A. B., Cambridge, Mass. (2).
Coffin, James H., Easton, Penn. (1).
Cole, Thomas, Salem, Mass. (1).
Coleman, Henry, Boston, Mass. (1).
Cooper, William, Hoboken, N. J. (9).
Corning, Erastus, Albany, N. Y. (6).
Couper, J. Hamilton, Darien, Ga. (1).
Crosby, Alpheus, Salem, Mass. (10).
Crosby, Thomas R., Hanover, N. H. (18).
Croswell, Edwin, Albany, N. Y. (6).
Curry, W. F., Geneva, N. Y. (11).

Dayton, Edwin A., Madrid, N. Y. (7).
Dean, Amos, Albany, N. Y. (6).
Dearborn, George H. A. S., Roxbury, Mass. (1).
Dekay, James E., New York (1).
DeLaski, John, Carver's Harbor, Me. (18).
Dewey, Chester, Rochester, N. Y. (1).
Dexter, G. M., Boston, Mass. (11).
Dillingham, W. A. P., Augusta, Me. (17).
Doggett, Wm. E., Chicago, Ill. (17).
Doolittle, L., Lenoxville, C. E. (11).
Ducatel, J. T., Baltimore, Md. (1).
Duffield, George, Detroit, Mich. (10).
Dumont, A. H., Newport, R. I. (14).
Duncan, Lucius C., New Orleans, La. (10).
Dunn, R. P., Providence, R. I. (14).

Easton, Norman, Fall River, Mass. (14).
Ely, Charles Arthur, Elyria, Ohio (4).
Emmons, Ebenezer, Williamstown, Mass. (1).
Engstrom, A. B., Burlington, N. J. (1).
Everett, Edward, Boston, Mass. (2).
Ewing, Thomas, Lancaster, Ohio (5).

Ferris, Dr. Isaac, New York (6).
Fillmore, Millard, Buffalo, N. Y. (7).
Fisher, Mark, Trenton, N. J. (10).
Fitch, Alexander, Hartford, Conn. (1).
Forbush, E. B., Buffalo, N. Y. (15).
Force, Peter, Washington, D. C. (4).
Foster, J. W., Hyde Park, Chicago, Ill. (1).
Foucon, Felix, Madison, Wis. (18).
Fowle, William B., Boston, Mass. (1).
Fox, Charles, Grosse Ile, Mich. (7).
Frazer, John F., Philadelphia, Pa. (1).
French, J. W., West Point, N. Y. (11).

Gavit, John E., New York (1).
Gay, Martin, Boston, Mass. (1).
Gibbon, J. H., Charlotte, N. C. (3).
Gillespie, W. M., Schenectady, N. Y. (10).
Gilmor, Robert, Baltimore, Md. (1).
Gould, Augustus A., Boston, Mass. (11).
Gould, B. A., Boston, Mass. (2).
Graham, James D., Washington, D. C. (1).
Gray, Alonzo, Brooklyn, N. Y. (13).
Gray, James H., Springfield, Mass. (6).
Greene, Benjamin D., Boston, Mass. (1).
Greene, Everett W., Madison, N. J. (10).
Greene, Samuel, Woonsocket, R. I. (9).
Greer, James, Dayton, Ohio (20).
Griffith, Robert E., Philadelphia, Penn. (1).
Griswold, John A., Troy, N. Y. (19).
Guest, William E., Ogdensburg, N. Y. (6).

Hackley, Charles W., New York (4).
Hale, Enoch, Boston, Mass. (1).
Hance, Ebenezer, Fallsington P. O., Pa. (7).
Hare, Robert, Philadelphia, Penn. (11).
Harlan, Joseph G., Haverford, Penn. (8).
Harlan, Richard, Philadelphia, Penn. (1).
Harris, Thaddeus W., Cambridge, Mass. (1).
Harrison, Jos., jr., Philadelphia, Pa. (12).
Hart, Simeon, Farmington, Conn. (1).
Haven, Joseph, Chicago, Ill. (17).
Hayden, H. H., Baltimore, Md. (1).
Hayward, James, Boston, Mass. (1).
Hilgard, Theo. C., St. Louis, Mo. (17).
Hickox, S. V. R., Chicago, Ill. (17).
Hincks, William, Toronto, C. W. (11).

Hitchcock, Edward, Amherst, Mass. (1).
Hodgson, W. B., Savannah, Ga. (10).
Holbrook, J. E., Charleston, S. C. (1).
Hopkins, Albert, Williamstown, Mass. (19).
Hopkins, James G., Ogdensburg, N. Y. (10).
Hopkins, T. O., Williamsville, N. Y. (10).
Hosford, Benj. F., Haverhill, Mass. (13).
Horton, William, Craigville, Orange Co., N. Y. (1).
Horton, C. V. R., Chaumont, N. Y. (10).
Houghton, Douglas, Detroit, Mich. (1).
Howland, Theodore, Buffalo, N. Y. (15).
Hubbert, James, Richmond, Province of Quebec (16).
Hunt, E. B., Washington, D. C. (2).
Hunt, Freeman, New York (11).

Ives, Moses B., Providence, R. I. (9).
Ives, Thomas P., Providence, R. I. (10).

Johnson, W. R., Washington, D. C. (1).
Jones, Catesby A. R., Washington, D. C. (8).

Keep, N. C., Boston, Mass. (13).
Kennicott, Robert, West Northfield, Ill. (12).
King, Mitchell, Charleston, S. C. (3).
Knickerbocker, Charles, Chicago, Ill. (17).

Lacklan, R., Cincinnati, Ohio (11).
Lapham, Increase A., Milwaukee, Wis. (3).
La Roche, R., Philadelphia, Pa. (12).
Lasel, Edward, Williamstown, Mass. (1).
Lawford, Frederick, Montreal, Canada (11).
Lederer Baron von, Washington, D. C. (1).
Lieber, Oscar M., Columbia, S. C. (8).
Lincklaen, Ledyard, Cazenovia, N. Y. (1).
Linsley, James H., Stafford, Conn. (1).
Lockwood, Moses B., Providence, R. I. (9).
Logan, William E., Montreal, Canada (1).
Loosey, Charles F., New York (12).
Lothrop, Joshua R., Buffalo, N. Y. (15).
Lyon, Sidney S., Jeffersonville, Ind. (20).

Maack, G. A., Cambridge, Mass. (18).
Mahan, D. H., West Point, N. Y. (9),
Marsh, Dexter, Greenfield, Mass. (1).
Marsh, James E., Roxbury, Mass. (10).

Mather, William W., Columbus, Ohio (1).
Maupin, S., Charlottesville, Va. (10).
McMahon, Mathew, Albany, N. Y. (11).
M'Conihe, Isaac, Troy, N. Y. (4).
Meade, George G., Philadelphia, Pa. (15).
Mitchell, O. M., Cincinnati, Ohio (3).
Mitchell, William, Poughkeepsie, N. Y. (2).
Mitchell, Wm. H., Florence, Ala. (17).
Morton, S. G., Philadelphia, Penn. (1).
Munroe, Nathan, Bradford, Mass. (6).

Newton, E. H., Cambridge, N. Y. (1).
Nicollett, J. N., Washington, D. C. (1).
Norton, J. P., New Haven, Conn. (1).
Noyes, J. O., New Orleans, La. (21).

Oakes, William, Ipswich, Mass. (1).
Olmsted, Alexander F., New Haven, Conn. (4).
Olmsted, Denison, New Haven, Conn. (1).
Olmsted, Denison, Jr., New Haven, Conn. (1).

Painter, Minshall, Lima, Pa. (7).
Parkman, Samuel, Boston, Mass. (1).
Perkins, Henry C., Newburyport, Mass. (18).
Perry, John B., Cambridge, Mass. (16).
Perry, M. C., New York (10).
Piggot, A. Snowden, Baltimore, Md. (10).
Plumb, Ovid, Salisbury, Conn. (9).
Pope, Charles A., St. Louis, Mo. (12).
Porter, John A., New Haven, Conn. (14).
Pugh, Evan, Centre Co., Penn. (14).

Redfield, William C., New York (1).
Resor, Jacob, Cincinnati, Ohio (8).
Robb, James, Fredericton, N. B. (4).
Robinson, Coleman T., Buffalo, N. Y. (15).
Rockwell, John A., Norwich, Conn. (10).
Rogers, Henry D., Glasgow, Scotland (1).
Rogers, James B., Philadelphia, Penn. (1).

Schaeffer, Geo. C., Washington, D. C. (1).
Scott, Joseph, Dunham, C. E. (11).
Senter, Harvey S., Aledo, Ill. (20).
Seward, William H., Auburn, N. Y. (1).

Sherwin, Thomas, Dedham, Mass. (11).
Silliman, Benjamin, New Haven, Conn. (1).
Skinner, John B., Buffalo, N. Y. (15).
Slack, J. H., Philadelphia, Pa. (12).
Smith, J. V., Cincinnati, Ohio (5).
Smith, Lyndon A., Newark, N. J. (9).
Sparks, Jared, Cambridge, Mass. (2).
Stimpson, William, Chicago, Ill. (12).
Sullivant, W. S., Columbus, Ohio (7).

Tallmadge, James, New York (1).
Taylor, Richard C., Philadelphia, Penn. (1).
Teschemacher, J. E., Boston, Mass. (1).
Thompson, Alexander, Aurora, N. Y. (6).
Thompson, Z., Burlington, Vt. (1).
Thurber, Isaac, Providence, R. I. (9).
Tillman, Samuel D., Jersey City, N. J. (15).
Tolderoy, James B., Fredericton, N. B. (11).
Torrey, John, New York (1).
Torrey, Joseph, Burlington, Vt.(2).
Totten, J. G., Washington, D. C. (1).
Townsend, Howard, Albany, N. Y. (10).
Townsend, John K., Philadelphia, Penn. (1).
Townsend, Robert, Albany, N. Y. (9).
Troost, Gerard, Nashville, Tenn. (1).
Tuomey, M., Tuscaloosa, Ala. (1).
Tyler, Edward R., New Haven, Conn. (1).

Vancleve, John W., Dayton, Ohio (1).
Vanuxem, Lardner, Bristol, Penn. (1).

Wadsworth, James S., Genesee, N. Y. (2).
Wagner, Tobias, Philadelphia, Penn. (9).
Walker, Joseph, Oxford, N. Y. (10).
Walker, Sears C., Washington, D. C. (1).
Walker, Timothy, Cincinnati, Ohio (4).
Walsh, Benjamin D., Rock Island, Ill. (17).
Warren, John C., Boston, Mass. (1).
Webster, H. B., Albany, N. Y. (1).
Webster, J. W., Cambridge, Mass. (1).
Webster, M. H., Albany, N. Y. (1).
Weed, Monroe, Wyoming, N. Y. (6).
Weyman, G. W., Pittsburg, Pa. (6).
Wheatland, Richard H., Salem, Mass. (13).
Whitman, Wm. E., Philadelphia, Pa. (23).

Whitney, Asa, Phila., Penn. (1).
Whittlesey, Charles C., St. Louis, Mo. (11)
Willard, Emma, Troy, N. Y. (15).
Wilson, W. C., Carlisle, Pa. (12).
Winlock, Joseph, Cambridge, Mass. (5).
Woodbury, L., Portsmouth, N. H. (1).
Woodman, John S., Hanover, N. H. (11).
Wright, John, Troy, N. Y. (1).
Wyman, Jeffries, Cambridge, Mass. (1).

Young, Ira, Hanover, N. H. (7).

[248 DECEASED MEMBERS.]

ADDRESS

OF

DR. JOHN L. LeCONTE,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

GENTLEMEN AND LADIES OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

THE founders of science in America, and the other great students of nature, who have in previous years occupied the elevated position in which I now stand, have addressed you upon many momentous subjects. In fulfilling the final duty, assigned to your Presidents by the laws of the Association, some have spoken to you in solemn and wise words concerning the duties and privileges of men of science: and the converse duties of the nation towards those earnest and disinterested promoters of knowledge. Others again have given you the history of the development of their respective branches of study, and their present condition, and have, in eloquent diction, commended to your gratitude those who have established on a firm foundation the basis of our modern systems of investigation.

The recent changes in our Constitution, by which you are led to expect from your two Vice-presidents, and from the Chairman of the Chemical Subsection, addresses on the progress made during the past year, restrain me from invading their peculiar fields of

labor, by alluding to scientific work which has been accomplished since our last meeting. While delicacy forbids me from so doing, I am equally debarred from repeating to you the brief sketch I endeavored to give at a former meeting[1] of the history, and present condition of Entomology in the United States.

But it has appeared to me that a few thoughts, which have impressed themselves on my mind, touching the future results to be obtained from certain classes of facts, not yet fully developed, on account of the great labor required for their proper comparison, may not be without value. Even if the facts be not new to you, I hope to be able, with your kind attention, to present them in such way as to be suggestive of the work yet to be done.

It has been perhaps said, or at least it has been often thought, that the first mention of the doctrine of evolution, as now admitted to a greater or less degree by every thinking man, is found in Ecclesiastes, i, 9:—

> "The thing that hath been is that which shall be; and that which is done is that which shall be done; and there is no new thing under the sun. Is there anything whereof it may be said, See, this is new? It hath been already of old time, which was before us."

Other references to evolutionary views in one form or another occur in the writings of several philosophers of classic times, as you have had recent cause to remember.

Whether these are to be considered as an expression of a perfect truth in the very imperfect language which was alone intelligible to the nation to whom this sacred book was immediately addressed on the one hand; and the happy guesses of philosophers, who by deep intuition had placed themselves in close sympathy with the material universe, on the other hand, I shall not stop to enquire. The discussion would be profitless, for modern science in no way depends for its magnificent triumphs of fact and thought upon any utterances of the ancients. It is the creation of patient intelligent labor of the last two centuries, and its results can be neither confuted nor confirmed by anything that was said, thought or done at an earlier period. I have merely referred to these indications of doctrines of evolution to recall to your minds that the two great schools of thought, which now divide philosophers, have existed from very remote times. They are,

[1] Proceedings Am. Assoc. Adv. Sc. xxi (Portland).

therefore, in their origin, probably independent of correct scientific knowledge.

You have learned from the geologists, and mostly from those of the present century, that the strata of the earth have been successively formed from fragments more or less comminuted by mechanical action, more or less altered by chemical combination and molecular rearrangement. These fragments were derived from strata previously deposited, or from material brought up from below, or even thrown down from above, or from the débris of organic beings which extracted their mineral constituents from surrounding media. Nothing new has been added, everything is old: only the arrangement of the parts is new, but in this arrangement definite and recognizable unchanged fragments of the old frequently remain. Geological observation is now so extended and accurate that an experienced student can tell from what formation, and even from what particular locality these fragments have been derived.

I wish to show that this same process has taken place in the organic world, and that by proper methods we can discover in our fauna and flora the remnants of the inhabitants of former geologic times, which remain unchanged, and have escaped those influences of variation which are supposed to account for the differences in the organic beings of different periods.

Should I succeed in this effort, we will be hereafter enabled in groups of animals which are rarely preserved in fossil condition, to reconstruct, in some measure, the otherwise extinct faunæ, and thus to have a better idea of the sequence of generic forms in time. We will also have confirmatory evidence of certain changes which have taken place in the outline of the land and the sea. More important still, we will have some indications of the time when greater changes have occurred, the rock evidence of which is now buried at the bottom of the ocean, or perhaps entirely destroyed by erosion and separations. Of these changes, which involved connections of masses of land, no surmise could be made, except through evidence to be gained in the manner of which I am about to speak.

My illustrations will naturally be drawn from that branch of zoology, with which I am most familiar; and it is indeed to your too partial estimate of my studies in that science, that I owe the privilege of addressing you on the present occasion.

There are, as you know, a particular set of Coleoptera which affect the seashore; they are not very numerous at any locality, but among them are genera which are represented in almost every country of the globe. Such genera are called cosmopolitan, in distinction to those which are found only in particular districts. Several of these genera contain species which are very nearly allied, or sometimes in fact undistinguishable and therefore identical along extended lines of coast.

Now it happens that some of these species, though they never stray from the ocean shore inland, are capable of living upon similar beaches on fresh water lakes, and a few are found in localities which are now quite inland.

To take an example, or rather several examples together, for the force of the illustration will be thereby greatly increased.

Along the whole of the Atlantic, and the greater part of the Pacific coast of the United States, is found in great abundance on sand beaches, a species of Tiger-beetle, *Cicindela hirticollis*, an active, winged and highly predaceous insect; the same species occurs on the sand beaches of the great lakes, and were it confined to these and similar localities, we would be justified in considering it as living there in consequence solely of the resemblance in the conditions of existence. But, it is also found, though in much less abundance, in the now elevated region midway between the Mississippi and Rocky Mountains. Now, this is the part of the continent which, after the division of the great intercontinental gulf in Cretaceous times, finally emerged from the bed of the sea, and was in the early and middle Tertiary converted into a series of immense fresh water lakes. As this insect does not occur in the territory extending from the Atlantic to beyond the western boundary of Missouri, nor in the interior of Oregon and California, I think that we should infer that it is an unchanged survivor of the species which lived on the shores of the Cretaceous ocean, when the intercontinental gulf was still open, and a passage existed, moreover, towards the south-west, which connected with the Pacific.

The example I have given you of the geographical distribution of *Cicindela hirticollis* would be of small value, were it an isolated case; nor would I have thought it worthy of occupying your time, on an occasion like this, which is justly regarded as one for the communication of important truth. This insect, which I have selected as a type for illustrating the methods of investigation to

which I invite your attention, is, however, accompanied more or less closely by other Coleoptera, which like itself are not particular as to the nature of their food, so long as it be other living insects, and apparently are equally indifferent to the presence of large bodies of salt water. First, there is *Cicindela lepida*, first collected by my father, near Trenton, New Jersey, afterwards found on Coney Island, near New York, and received by me from Kansas and Wisconsin; not, however, found west of the Rocky Mountains. This species, thus occurring in isolated and distant localities, is probably in process of extinction, and may or may not be older than *C. hirticollis*. I am disposed to believe, as no representative species occurs on the Pacific coast, and from its peculiar distribution, that it is older. Second, there is *Dyschirius pallipennis*, a small Carabide, remarkable among other species of the genus by the pale wing covers, usually ornamented with a dark spot. This insect is abundant on the Atlantic coast from New York to Virginia, unchanged in the interior parts of the Mississippi valley, represented at Atlantic City, New Jersey, by a larger and quite distinct specific form, *C. sellatus*, and on the Pacific coast by two or three species of larger size and different shape, which in my less experienced youth I was disposed to regard as a separate genus *Akephorus*. This form is, therefore, in a condition of evolution,—how, I know not,—our descendants may. The Atlantic species are winged, the Pacific ones, like a large number of insects of that region are without wings.

Accompanying these are Coleoptera of other families, which have been less carefully studied, but I will not trespass upon your patience by mentioning more than two. *Bledius pallipennis* (*Staphylinidæ*) is found on salt marshes near New York, on the Southern sea coast, and in Kansas,—*Ammodonus fossor;* a wingless Tenebrionide, Trenton, seashore near New York, and valley of Mississippi at St. Louis; thus nearly approximating *Cicindela lepida* in distribution.

We can thus obtain by a careful observation of the localities of insects, especially such as affect seashore or marsh, and those which being deprived of their favorite surroundings, have shown, if I may so express myself, a patriotic clinging to their native soil, most valuable indications in regard to the time at which their unmodified ancestors first appeared upon the earth. For it is obvious that no tendency to change in different directions by " nu-

merous successive slight modifications"[1] would produce a uniform result in such distant localities, and under such varied conditions of life. Properly studied, these indications are quite as certain as though we found the well preserved remains of these ancestors in the mud and sand strata upon which they flitted or dug in quest of food.

Other illustrations of survivals from indefinitely more remote times I will also give you, from the Coleopterous fauna of our own country, though passing time admonishes me to restrict their number.

To make my remarks intelligible, I must begin by saying that there are three great divisions of Coleoptera, which I will name in the order of their complication of structural plan: 1. Rhynchophora; 2. Heteromera; 3. Ordinary or normal Coleoptera; the last two being more nearly allied to each other than either is to the first. I have in other places exposed the characters of these divisions, and will not detain you by repeating them.

From Palæontological evidence derived from other branches of zoology, we have a right to suppose, if this classification be correct, that these great types have been introduced upon the earth in the order in which I have named them.

Now, it is precisely in the first and second series that the most anomalous instances of geographical distribution occur; that is to say, the same or nearly identical genera are represented by species in very widely separated regions, without occurring in intermediate or contiguous regions. Thus there is a genus *Emeax*, founded by Mr. Pascoe, upon an Australian species, which, when I saw it, I recognized as belonging to *Nyctoporis*, a California genus, established many years before; and in fact barely specifically distinct from *N. galeata*. Two other examples are *Othnius* and *Eupleurida*, United States genera, which are respectively equivalent to *Elacatis* and *Ischalia*, found in Borneo. Our native genera *Eurygenius* and *Toposcopus*, are represented by scarcely different forms in Australia. All these belong to the second series (*Heteromera*), and the number of examples might be greatly increased with less labor on my part than patience on yours.

A single example from the Rhynchophora, and I will pass to another subject.

On the sea coast of California, extending to Alaska, is a very

[1] Origin of Species, 1869, 227.

anomalous insect, whose affinities are difficult to discern, called *Emphyastes fucicola*, from its occurrence under the sea-weed cast up by the waves. It is represented in Australia by several species of a nearly allied genus Aphela, found in similar situations.

In all entomological investigations relating to geographical distribution, we are greatly embarrassed by the multitude of species, and by the vague and opinionative genera founded upon characters of small importance. The Coleoptera alone, thus far described, amount to over 60,000 so-called species, and there are from 80,000 to 100,000 in collections. Under these circumstances it is quite impossible for one person to command either the time or the material to master the whole subject, and from the laudable zeal of collectors to make known what they suppose to be new objects, an immense amount of synonymy must result. Thus in the great Catalogus Coleopterorum of Gemminger and Harold, a permanent record of the untiring industry of those two excellent entomologists, species of the genus *Trechicus* founded by me upon a small North American insect, are mentioned under five generic names, only one of which is recognized as a synonym of another. These generic headings appear in such remote pages of the volume as 135, 146 and 289.

The two closely allied genera of Rhynchophora mentioned above are separated by no less than 168 pages.

It is therefore plain, that before much progress can be made in the line of research which I have proposed to you, whereby we may recover important fragments of the past history of the earth, Entomology must be studied in a somewhat different manner from that now adopted. The necessity is every day more apparent that descriptions of heterogeneous material are rather obstructive than beneficial to science, except in the case of extraordinary forms likely to give information concerning geographical distribution or classification. Large typical collections affording abundant material for comparison, for the approximation of allied forms, and the elimination of doubtful ones must be accumulated; and in the case of such perishable objects, as those we are now dealing with, must be placed where they can have the protecting influences both of climate and personal care.

At the same time, for this investigation, the study of insects is peculiarly suitable; not only on account of the small size, ease of collecting, and little cost of preserving the specimens, but because

from their varied mode of life in different stages of development, and perhaps for other reasons, the species are less likely to be destroyed in the progress of geological changes.[1] Cataclysms and submergences, which would annihilate the higher animals, would only float the temporarily asphyxiated insect, or the tree trunks containing the larvæ and pupæ to other neighboring lands. However that may be, I have given you some grounds for believing, that many of the species of insects now living existed in the same form before the appearance of any living genera of mammals, and we may suppose that their unchanged descendants will probably survive the present mammalian fauna, including our own race.

I may add, moreover, that some groups, especially in the Rhynchophora, which, as I have said above, I believe to be the earliest introduced of the Coleoptera, exhibit with compact and definite limits, and clearly defined specific characters, so many generic modifications, that I am compelled to think that we have in them an example of the long sought unbroken series, extending in this instance from early mesozoic to the present time, and of which very few forms have become extinct.

I have used the word *species* so often, that you will doubtless be inclined to ask, what, then, is understood by a species? Alas! I can tell you no more than has been told recently by many others. It is an assemblage of individuals, which differ from each other by very small or trifling and inconstant characters, of much less value than those in which they differ from any other assemblage of individuals. Who determines the value of these characters? The experienced student of that department to which the objects belong. Species are, therefore, those groups of individuals representing organic forms which ARE RECOGNIZED as such by those who from natural power and education are best qualified to judge.

You perceive, therefore, that we are here dealing with an entirely different kind of information from that which we gain from the physical sciences; everything there depends on accurate observation, with strict logical consequences derived therefrom. Here the basis of our knowledge depends equally on accurate and trained observation, but the logic is not formal but perceptive.

[1] For a fuller discussion of these causes, and of several other subjects which are briefly mentioned in this address, the reader may consult an excellent memoir by my learned friend, Mr. Andrew Murray, "On the Geographical Relations of the Chief Coleopterous Faunæ." (Journal of Linnæan Society, Zoology, Vol. xi.)

This has been already thoroughly recognized by Huxley[1] and Helmholtz,[2] and others, but we may properly extend the inquiry into the nature and powers of this æsthetic perception somewhat farther. For it is to this fundamental difference between biological and physical sciences that I will especially invite your attention.

Sir John Lubbock,[3] quoting from Oldfield[4] mentions that certain Australians "were quite unable to realize the most vivid artistic representations. On being shown a picture of one of themselves, one said it was a ship, another a kangaroo, not one in a dozen identifying the portrait as having any connection with himself."

These human beings, therefore, with brains very similar to our own, and as is held by some persons, potentially capable of similar cultivation with ourselves, were unable to recognize the outlines of even such familiar objects as the features of their own race. Was there any fault in the drawing of the artist? Probably not. Or in the eye of the savage? Certainly not, for that is an optical instrument of tolerably simple structure, which cannot fail to form on the retina an accurate image of the object to which it is directed. Where then is the error? It is in the want of capacity of the brain of the individual (or rather the race in this instance) to appreciate the resemblance between the outline, the relief, the light and shade of the object pictured, and the flat representation in color: in other words, a want of "artistic tact" or æsthetic perception.

A higher example of a similar phenomenon I have myself seen: many of you too have witnessed it, for it is of daily occurrence. It is when travellers in Italy having penetrated to the inmost chamber of the Temple of Art, even the Hall of the Tribune at Florence, stand in presence of the most perfect works of Art, which it has been given to man to produce, and gaze upon them with the same

[1] "A species is the smallest group to which distinctive and invariable characters can be assigned." (Principles and Methods of Palæontology, Smithsonian Report, 1869, 378).

[2] "I do not mean to deny that, in many branches of these sciences, an intuitive perception of analogies and a certain artistic tact play a conspicuous part. In natural history . . . . . . it is left entirely to this tact, without a clearly definable rule, to determine what characteristics of species are important or unimportant for purposes of classification, and what divisions of the animal or vegetable kingdom are more natural than others." (Relation of the Physical Sciences to Science in General. Smiths. Report, 1871, 227.)

[3] Prehistoric Times, p. 440.

[4] On the Aborigines of Australia. Trans. Ethnological Soc. New Series, Vol. 3.

indifference that they would show to the conceptions of mediocre artists exhibited in our shops.

Perhaps they would even wonder what one can find to admire in the unrivalled collection, which is there assembled.

There is surely wanting in the minds of such persons that high, æsthetic sense, which enables others to enter into spiritual harmony with the great artists whose creations are before them.

Creations I said, and I use the word intentionally. If there is one power of the human soul, which more nearly than any other approaches the faculty of creation, it is that by which the almost inspired artist develops out of a rude block of stone, or out of such mean materials as canvass and metallic pastes of various colors, figures which surpass in beauty, and in power of exciting emotion, the objects they profess to represent.

Yet these unæsthetic and nonappreciative persons are just as highly educated, and in their respective positions as good and useful members of the social organism as any that may be found. I maintain only, they would never make good students of biology.

In like manner, by way of illustrating the foregoing observations, there are some, who in looking at the phenomena of the external Universe, may recognize only Chance, or the "fortuitous concourse of atoms," producing certain resultant motions. Others, having studied more deeply the nature of things, will perceive the existence of laws, binding and correlating the events they observe. Others again, not superior to the latter in intelligence, nor in power of investigation, may discern a deeper relation between these phenomena, and the indications of an intellectual or æsthetic or moral plan, similar to that which influences their own actions, when directed to the attaining of a particular result.

These last will recognize in the operations of nature the direction of a Human Intelligence, greatly enlarged, capable of modifying at its will influences beyond our control; or they will appreciate in themselves a resemblance to a superhuman intelligence which enables them to be in sympathy with its actions.

Either may be true in individual instances of this class of minds; one or other must be true; I care not which, for to me the propositions are in this argument identical, though in speculative discussions, they may be regarded as at almost the opposite poles of religious belief. All that I plead for is, that those who have not this perceptive power, and who in the present condition of

scientific discussion are numerically influential, will have tolerance for those who possess it; and that the ideas of the latter may not be entirely relegated to the domain of superstition and enthusiasm.

In the case of the want of perception of the Australian, a very simple test can be applied. It is only to photograph the object represented by the artist, and compare the outlines and shades of the photograph, with those of the picture. If they accord within reasonable limits the picture is correct to that extent; at least, however bad the artist, the human face could never be confounded with a ship, or a kangaroo.

Can we apply a similar test to the works of nature? I think we can. Suppose that man,—I purposely use the singular noun to indicate that all human beings of similar intelligence and education working towards a definite end, will work in a somewhat similar manner,—suppose, then I say, that man, endeavoring to carry out some object of importance, devises a method of so doing, and creates for that purpose a series of small objects, and we find that these small objects naturally divide and distribute themselves in age and locality, in a similar manner to that in which the species of a group of organisms are divided in space, and distributed in time; and that the results of man's labor are thus divided and distributed on account of the necessary inherent qualities of his intelligence and methods of action, is not the resemblance between human reason and the greater powers which control the manifestations of organic nature apparent?

I now simply present to you this investigation. Time is wanting for me to illustrate it by even a single example, but I feel sure that I have in the minds of some of you already suggested several applications of it to the principle I wish to teach:—the resemblance in the distribution of the works of nature to that of human contrivances evolved for definite purposes.

If this kind of reasoning commends itself to you, and you thus perceive resemblances in the actions of the Ruler of the Universe to those of our own race, when prompted by the best and highest intellectual motives, you will be willing to accept the declaration of the ancient text, "He doeth not evil, and abideth not with the evil inclined. Whatever he hath done is good;"[1] or that

[1] Desatir, p. 2.

from our own canon of Scripture: "With him is wisdom and strength, he hath counsel and understanding."[1]

The æsthetic character of Natural History, therefore, prevents the results of its cultivation from being worked out with the precision of a logical machine, such as with correct data of observation and calculation would be quite sufficient to formulate the conclusions of physical investigation. According as the perception of the relations of organic beings among themselves becomes more and more enlarged, the interpretation of these relations will vary within limits; but we will be continually approximating higher mental or spiritual truth.

This kind of truth can never be revealed to us by the study of inorganic aggregations of the universe. The molar, molecular and polar forces, by which they are formed, may be expressed, so far as science has reduced them to order, by a small number of simply formulated laws, indicative neither of purpose nor intelligence, when confined within inorganic limits. In fact, taking also the organic world into consideration, we as yet see no reason why the number of chemical elements known to us should be as large as it is, and go on increasing almost yearly with more minute investigations. To all appearance, the mechanical and vital structure of the universe would remain unchanged, if half of them were struck out of existence.

Neither is there any evidence of intelligence or design in the fact that the side of the moon visible to us exhibits only a mass of volcanoes.

Yet upon the earth, without the volcano and the earthquake, and the elevating forces of which they are the feeble indications, there would be no permanent separation of land and water; consequently no progress in animal and vegetable life beyond what is possible in the ocean. To us, then, as sentient beings, the volcano and the earthquake, viewed from a biological standpoint, have a profound significance.

It is indeed difficult to see in what manner the student of purely physical science is brought to a knowledge of any evidences of intelligence in the arrangement of the Universe. The poet, inspired by meditating on the immeasurable abyss of space, and the transcendent glories of the celestial orbs has declared,

"The undevout astronomer is mad,"

[1] Job, xii, 13.

and his saying had a certain amount of speciousness, on account of the magnitude of the bodies and distances with which the student of the stars is concerned. This favorite line is, however, only an example of what an excellent writer has termed "the unconscious action of volition upon credence," and it is properly in the correlations of the inorganic with the organic world, that we may hope to exhibit, with clearness, the adaptations of plan prefigured and design executed.

In the methods and results of investigation, the mathematician differs from both the physicist and the biologist. Unconfined like the former, by the few simple relations by which movements in the inorganic world are controlled, he may not only vary the form of his analysis, almost at pleasure, making it more or less transcendental in many directions, but he may introduce factors or relations, apparently inconceivable in real existences, and then interpret them into results quite as real as those of the legitimate calculus with which he is working, but lying outside of its domain.

If biology can ever be developed in such manner that its results may be expressed in mathematical formulæ, it will be the pleasing task of the future analyst, to ascertain the nature of the inconceivable (or imaginary as they are termed in mathematics) quantities which must be introduced when changes of form or structure take place. Such will be analytical morphology, in its proper sense; but it is a science of the future, and will require for its calculus a very complex algebra.

In the observation of the habits of inferior animals, we recognize many complications of action, which though directed to the accomplishment of definite purposes, we do not entirely comprehend. They are, in many instances, not the result of either the experience of the individual, or the education of its parents, who in low forms of animals frequently die before the hatching of the offspring. These actions have been grouped together, whether simple or complex, as directed by what we are pleased to call instinct, as opposed to reason. Yet there is every gradation between the two.

Among the various races of dogs, the companions of man for unnumbered centuries, we observe not only reasoning powers of a rather high order, but also distinct traces of moral sentiments, similar to those possessed by our own race. I will give no examples, for many may be found in books with which you are familiar.

Actions evincing the same mental attributes are also noticed in wild animals, which have been tamed. You will reply, that these qualities have been developed by human education; but not so, there must have been a latent capacity in the brain to receive the education, and to manifest the results by the modification of the habits. Now it is because we are vertebrates, and the animals of which I have spoken are vertebrates, that we understand, though imperfectly, their mental processes, and can develop the powers that are otherwise latent. Could we comprehend them more fully we would find, and we do find from time to time in the progress of our inquiries, that what was classed with instinct is really intellection.

When we attempt to observe animals belonging to another subkingdom, Articulata, for instance, such as bees, ants, termites, etc., which are built upon a totally different plan of structure, having no organ in common with ourselves, the difficulty of interpreting their intellectual processes, if they perform any, is still greater. The purposes of their actions we can only divine by their results. But anything more exact than their knowledge of the objects within their scope, more ingenious than their methods for using those objects, more complex, yet well devised than their social and political systems, it is impossible to conceive.

We are not warranted in assuming that these actions are instinctive, which if performed by a vertebrate we would call rational. Instead of concealing our ignorance under a word which thus used, comes to mean nothing, let us rather admit the existence here of a rational power, not only inferior to ours, but also different.

Thus proceeding, from the highest forms in each type of animal life to the lower, and even down to the lowest, we may be prepared to advance the thesis, that all animals are intelligent, in proportion to the ability of their organization to manifest intelligence to us, or to each other; that wherever there is voluntary motion, there is intelligence:— obscure it may be, not comprehended by us, but comprehended by the companions of the same low grade of structure.

However this may be, I do not intend to discuss the subject at present, but only wish in connection with this train of thought to offer two suggestions.

The first is, that by pursuing different courses of investigation in biology, we may be led to opposite results. Commencing with

the simplest forms of animal life, or with the embryo of the higher animals, it may be very difficult to say at what point intelligence begins to manifest itself; our attention is concentrated, therefore, upon those functions which appear to be the result of purely mechanical arrangements, acted upon by external stimuli. The animal becomes to our perception an automaton, and in fact, by excising some of the nervous organs last developed in its growth, we can render an adult animal an automaton, capable of performing only those habitual actions to which its brain, when in perfect condition, had educated the muscles of voluntary motion. On the other hand, commencing with the highest group in each type, and going downwards, either in structural complication, or in age of individual, it is impossible to fix the limit at which intelligence ceases to be apparent.

I have in this subject, as in that of tracing the past history of our insects, in the first part of this address, preferred the latter mode of investigation; taking those things which are nearest to us in time or structure, as a basis for the study of those more remote.

The second consideration is, since it is so difficult for us to understand the mental processes, whether rational or instinctive (I care not by what name they are called), of beings more or less similar, but inferior to ourselves; we should exercise great caution when we have occasion to speak of the designs of One who is infinitely greater. Let us give no place to the crude speculations of would-be-teleologists, who are indeed, in great part refuted already by the progress of science, which continually exhibits to us higher and more beautiful relations between the phenomena of Nature "than it hath entered into the mind of man to conceive." Let not our vanity lead us to believe that because God has deigned to guide our steps a few paces on the road of truth, we are justified in speaking as if He had taken us into intimate companionship, and informed us of all His counsels.

If I have exposed my views on these subjects to you in an acceptable manner, you will perceive that in minds capable of receiving such impressions, biology can indicate the existence of a creative or directive power, possessing attributes, some of which resemble our own, and controlling operations which we may feebly comprehend. Thus far Natural Theology, and no farther.

What then is the strict relation of Natural History or biology to that great mass of learning and influence which is commonly

called Theology; and to that smaller mass of belief and action which is called Religion?

Some express the relation very briefly, by saying that Science and Religion are opposed to each other. Others again that they have nothing in common. These expressions are true of certain classes of minds; but the greater number of thinking and educated persons see, that though the ultimate truths taught by each are of quite distinct nature, and can by no means come in conflict, inasmuch as they have no point in common; yet so far as these truths are embodied in human language, and manipulated by human interests, they have a common dominion over the soul of man. According to the method of their government, they may then come into collision even as the temporal and spiritual sovereigns of Japan occasionally did, before the recent changes in that country.

In answering the query above proposed, it will be necessary to separate the essential truths of religion from the accessories of tradition, usage, and most of all, organizations and interpretations, which have in the lapse of time gathered around the primitive or revealed truth.

With the latter, the scientific man must deal exactly like other men, he must take it, or reject it, according to his spiritual gifts; but he must not, whatever be his personal views, discuss it or assail it *as a man of science*, for within his domain of investigation it does not belong.

With regard to the accessories of traditions, interpretations, etc., our answer may be clearer, when we have briefly reviewed some recent events in what has been written about as the Conflict of Religion and Science. Some centuries ago, great theological disgust was produced by the announcement that the sun and not the earth was the centre of the planetary system. A few decades ago profound dissatisfaction was shown that the evidence of organic life on the planet was very ancient. Recently some annoyance has been exhibited because human remains have been found in situations where they ought not to have been, according to popularly received interpretations; and yet more recently much apprehension has been felt at the possible derivation of man from some inferior organism; an hypothesis framed simply because in the present condition of intellectual advancement, no other can be suggested.

Yet all these facts, but the last, which still is an opinion, have been accepted, after more or less bitter controversy on both sides, and the fountain of spiritual truth remains unclouded and undiminished. New interpretations for the sacred texts, supposed to be in conflict with the scientific facts, have been sought and found without difficulty. These much feared facts have, moreover, given some of the strongest and most convincing illustrations to modern exhortation and religious instruction.

Thus, then, we see that the influence of Science upon Religion, has been beneficial. Scholastic interpretations founded upon imperfect knowledge, or no knowledge, but mere guess, have been replaced by sound criticism of the texts, and their exegesis in accordance with the times and circumstances for which they were written.

It must be conceded by fair minded men of both sides that these controversies were carried on at times with a rudeness of expression and bitterness of feeling now abhorrent to our usages. The intellectual wars of those days partook of the brutality of physical war, and the horrors of the latter, as you know, have been ameliorated only within very few years.

I fear that the unhappy spirit of contention still survives, and that there are yet a few who fight for victory rather than for truth. The deceptive spirit of Voltaire still buds forth occasionally; he, who, as you remember, disputed the organic nature of fossil shells, because in those days of schoolmen, their occurrence on mountains would be used by others as a proof of a universal Noachian deluge. The power of such spirits is fortunately gone for any potent influence for evil, gone with the equally obstructive influence of the scholastics with whom they formerly contended.

Since then, there is no occasion for strict Science and pure Religion to be in conflict, how shall the peace be kept between them?

By Toleration and Patience. Toleration towards those who believe less than we do, in the hope that they, by cultivation or inheritance of æsthetic perception, will be prepared to accept something more than Matter and Energy in the Universe, and to believe that Vitality is not altogether undirected Colloid Chemistry.

Toleration also towards those who, on what we think misunderstood or insufficient evidence, demand more than we are prepared to admit, in the hope that they will revise additional texts which

seem to conflict, or may hereafter conflict with facts deduced from actual study of Nature, and thus prepare their minds for the reception of such truths as may be discovered, without embittered discussions.

Patience, too, must be counselled. For much delay will ensue before this desired result is arrived at; patience under attack, patience under misrepresentation, but never controversy.

Thus will be hastened the time, when the glorious, all sufficient spiritual light, which though given through another race, we have adopted as our own, shall shine with its pristine purity, freed from the incrustations with which it has been obscured by the vanity of partial knowledge, and the temporary contrivances of human polity.

So, too, by freely extended scientific culture, may we hope that the infinitely thicker and grosser superstitions and corruptions will be removed, which greater age and more despotic governments have accumulated around the less brilliant, though important religions of our Asiatic Aryan relatives. These accretions being destroyed, the principal difficulty to the reception by those nations of higher spiritual truths will be obviated, and the intelligent Hindoo or Persian will not be tardy in recognizing in the pure life and elevated doctrine of the sincere Christian, an addition to, and fuller expression of religious precepts with which he is familiar. In this manner alone may be realized the hope of the philosopher, the dream of the poet, and the expectation of the theologian. A Universal Science, and a Universal Religion, coöperating harmoniously for the perfection of man and the glory of his Creator.

REPORTS OF COMMITTEES[1].

REPORT OF THE COMMITTEE ON WEIGHTS, MEASURES AND COINAGE.

THE object for which the committee on weights, measures and coinage of the Association for the Advancement of Science was originally appointed, was not that it should consider matters at that time definitely laid before it, and after reporting be discharged, but that, like the analogous committee of the British Association, it should take cognizance of all the movements which may be going on throughout the world in regard to matters relating to this subject, and should advise the Association, from time to time, as to the modes in which it might promote the general progress of improvement by the expression of its sympathies, or by invoking the action of other bodies whose coöperation might be likely to subserve the same cause.

The purpose of this report is, therefore, to call the attention of the Association, at this time, to the results of the recent international diplomatic conference, of which the sessions were concluded in the month of March last; and to the international convention adopted by that Congress, and signed by the diplomatic representatives of twenty-one nations, among whom the representative of the United States is included.

This conference was invited early in the year 1870, at the instance of the European Geodesic Association, by the government of France. The invitation was extended to all the nations with which France is in friendly diplomatic intercourse, and its object, as stated, was to ask the coöperation of such nations in an endeavor, through an international commission, to provide adequate securities for the perpetuation, unaltered forever, of the basic units of the metric system; for the discussion and final settlement of any question which had been or might be raised as to the literal conformity of the prototype standards with the natural dimensions which they purport to represent; and for the provision of

[1] For notice of reports from several committees, see Report of General Secretary.

authentic copies of those prototypes to be deposited with the several metric nations, and all others which should desire them, as local standards of comparison and verification. The invitation was generally accepted, and delegates appointed by the different nations were assembled for the first time in the summer of 1870, in Paris. The delegates appointed on behalf of the United States were Prof. Joseph Henry, Secretary of the Smithsonian Institution, and Prof. J. E. Hilgard, of the Coast Survey, now President of this Association. At this earliest meeting, at which Prof. Henry appeared for the United States, certain general principles were agreed upon for the guidance of future proceedings; but in consequence of the war, which raged with such violence between France and Germany during that year, no active measures were attempted.

A second meeting took place in 1872, at which there were represented, by their delegates, thirty different nations; Prof. Hilgard appearing on behalf of the United States. On this occasion, after mature deliberation and discussion, it was resolved that the original standard metre and kilogramme should be adhered to as standards of length and weight. The original standard metre had been what is called an end-metre, or a metre *à bout.* But as, in comparisons with such a metre, the extremities are liable to be injured by repeated contacts, however delicate, the commission resolved that the new metres should be line-metres, or metres *à trait;* that is, measures in which the standard is the distance between two delicately traced lines on the surface of the metal; these lines to be observed microscopically, and never touched.

For material they adopted an alloy of platinum and iridium, ten per cent. of the metal last named being united with ninety per cent. of pure platinum. Of this material, also, they resolved to make the kilogramme. The expansibility of this material is slight, while its hardness and rigidity are great, and it resists all acids and all ordinary artificial heat. It is only fusible in a furnace specially constructed for the purpose, in which the material, supported on a bed of lime, is exposed to the direct action of many jets of the oxy-hydrogen blowpipe. In order to secure the highest degree of rigidity in the mass of metal forming the standard metre, it was determined to give to the bar a cross section resembling in part the letter X, and in part the capital H, the lines de-

noting the limits of the standard to be traced on the bottom of the trough thus formed, on one side of the cross-bar of the H.

Inasmuch, also, as it was designed to furnish all the metric nations with carefully compared and verified standards accompanied by their certified equations, and as it was desirable that these standards should be as nearly as possible identical in character in every respect, it was further resolved to construct the whole from a single ingot, formed at one operation of melting.

The difficult and responsible duty of accurately preparing the bars in accordance with these rules was intrusted to the delegates constituting the French section of the commission. An executive committee, chosen from the delegates of the different nations, to the number of twelve, in which committee our country is represented by Prof. Hilgard, was charged with the subsequent duty of receiving, comparing and verifying these standards. These verifications having been accomplished, the committee were required to call the entire commission together and to deliver over to that body the standards thus finally completed.

It being evident that, in order to secure permanently to the nations represented, and to the world, the benefits contemplated in the institution of this commission, some permanent organization would be necessary to take charge of the standards created, to attend to their distribution, to prepare new ones if such should hereafter be necessary; to recompare, hereafter, those originally distributed if such verification should be desired, and further to compare and verify standards of measure of any kind, whether metric or not, for nations or for municipalities, or for corporate bodies or even for individuals, it was finally resolved that the French government should be requested to invite a diplomatic conference of the nations for the purpose of advising as to the proper plan of such an organization, and as to the means of maintaining it.

In consequence of this suggestion such an invitation was issued in January, 1873. On the receipt of the invitation from the French government by that of the United States, the President of the National Academy of Sciences was invited, by the Secretary of State, to lay before him such information in regard to the nature of the proposed scheme, its relations to the interests of science, and its more direct importance to the material welfare of mankind, as might enable him to advise the President of the United States

as to the expediency of acceding to the invitation. The president of the Academy referred the subject to a committee, by whom a formal report was drawn up which was presented to the President of the Academy and by him transmitted to the Secretary.

The impression produced by this upon the mind of the President of the United States was so favorable that without hesitation he appointed Mr. Washburne, our minister at Paris, to represent our country in the proposed diplomatic conference. The call for the conference was issued in December, 1874, and the conference itself was actually convened in March, 1875. A convention was entered into by the delegates, on behalf of the nations represented by them, in which it was stipulated that provision should be made, by appropriations *pro-rata* from the different assenting nations, for the maintenance of the international bureau. A scheme of organization for this bureau was approved, and a budget in which estimates were embraced in regard to the original cost of construction and preliminary operations, and in regard to the future annual support of the bureau, was also approved.

This committee see no occasion for going more particularly into details in regard to the plan of the proposed permanent bureau, inasmuch as the president of the Association, who is a member of the executive committee of the international commission, will probably make a communication, written or oral, to the Association on the subject. The point which the committee desire to press upon the Association is this: The delegates to the diplomatic conference who have affixed their signatures to the convention, have done so, in a few instances, subject to the approval of their governments; others have acted with the full authority of their governments. It is gratifying to know that the President of the United States, on having been consulted by Mr. Washburne upon the question of affixing his signature, was authorized, by telegraph, to do so, and signed the convention accordingly.

The United States are, therefore, one of the signatory powers; and so far as the action of the executive government can go, we are a member of an international league more honorable to civilization than almost any other that was ever entered into by such high contracting parties.

As, however, in order that our engagements may be fulfilled, it is necessary that our Congress should make provision to defray the portion of the accruing expense which falls to our share, it

seems desirable that an expression should be laid before Congress by the scientific men of the country, signifying their estimate of the importance of this measure, and praying them to make the slight appropriations required. These will amount to not more than $10,000 in the first instance, and the future annual smaller sum of $900.

It is to be considered that this organization is not designed merely to advance the interests of the metric system of weights and measures, or to serve as a means of promoting the extension of that system. Its design is higher than that. To secure the universal adoption of the metric system would be undoubtedly to confer an immense and incalculable benefit upon the human race; but it would be a benefit felt mainly in the increased facilities which it would afford to commerce and to exactness in matters that concern the practical life of humanity. But to secure that severe accuracy in standards of measurement which transcends all the wants of ordinary business affairs, yet which, in the present advanced state of science, is the absolutely indispensable condition of higher progress, is an object of interest to the investigators of nature immensely superior to anything which contemplates only the increase of the wealth of nations.

This international bureau proposes now to provide for science precisely that which science in the present age of the world demands,—such minute exactness of measurement, that observations of the most delicate character which may be made in Germany, or Italy, or France, or England, may be exactly and quantitatively known to the investigator in the United States, who reads the measures as they are set down in the journals and the memoirs in which the original observations are described. It is of secondary consequence whether the standards are metric standards, or standards such as are in use among ourselves. This bureau will equally verify them all, and compare them all with standards of other nations founded on different linear bases, so long as such differences shall continue to exist. It is, therefore, not merely an international bureau of weights and measures, but it may, with equal propriety, be called an international bureau for the promotion of exactness in scientific determinations. And it will be as much the organ of institutions like this Association, like the National Academy, like the Royal Society, like the French Institute, etc., as it will be that of the governments establishing

it. The committee, therefore, recommend that a memorial should be drawn up and signed by all the members of the Association, whether here present or now at their homes, urging Congress, in behalf of American science, to make the trivial appropriation required to enable our country to be a participator in the maintenance of an organization so honorable to our age and so important to the interests we have at heart.

F. A. P. Barnard, Chairman,
J. E. Hilgard,
H. A. Newton,
J. Lawrence Smith,
Joseph Henry,
W. B. Rogers,
Benjamin Peirce,
E. B. Elliott,
} *Committee.*

Detroit, August 17, 1875.

After the acceptance of the Report, the following Resolutions, recommended by the Standing Committee, were unanimously adopted:—

Whereas, in the investigations of science, precision in the determination of quantities is essential to the discovery of truth, and therefore every measure which has for its object to secure or maintain accuracy in the standards of measurement is directly promotive of scientific advancement, and is of interest to any investigator,

And whereas it has been made known to this Association, that a convention was entered into early in the present year by the leading powers of the civilized world, through their diplomatic representatives, providing for the creation and maintenance, in the city of Paris, of an organization to be called "The International Bureau of Weights and Measures," for the preparation, verification and distribution to the governments of all the assenting powers of accurate standards of measurement, and for the preservation unaltered forever of the prototypes from which such standards are derived; to which convention the government of the United States became a party by the assent of the President, and the signature of its authorized representative,

And whereas, for the purpose of defraying the cost of the necessary buildings and equipment and for the maintenance of such Bureau in the discharge of its proposed functions, it is provided in the said convention

that each of the high contracting powers shall contribute according to a scale dependent on its population and its relation to the metric system, the amount of such contribution being in every case inconsiderable and entirely insignificant in comparison with the advantages to be derived,

Therefore

Resolved, that a memorial address to the Congress of the United States on behalf of this Association be prepared for signature at this present meeting, praying the Senate to confirm the action of the Executive Department, and praying Congress to make early provision to discharge the obligations resting upon us, in consequence of the provision of the international convention above mentioned, distributing the burden of expense attendant on the creation of the international bureau of Weights and Measures, and on its subsequent maintenance among the signatory powers, and that the said memorial be signed not only by the members of this Association here present, but also by such of those not in attendance as may choose to attach their signatures, to the end that the prayer of the memorial may be made if possible unanimous.

Resolved, further, that such memorial, when so signed, be transmitted in duplicate to the presiding officers of the Senate and House of Representatives, by the President of the Association, immediately on the assembling of the forty-fourth Congress in December next.

In pursuance of this action, the following memorial was drafted and numerously signed before the adjournment of the Association.

To the Senate and House of Representatives of the United States in Congress assembled:

The undersigned, Members of the American Association for the Advancement of Science, having learned with great satisfaction, that a convention has been entered into by the leading nations of the world for the establishment and maintenance of an International Bureau of Weights and Measures, with the object of promoting permanence, precision and uniformity in the standards, at the joint charge of the contracting powers; and that the Government of the United States has agreed to the same through its diplomatic representative, subject to the ratification of the Senate, do now, for the considerations set forth in the accompanying report and resolutions, respectfully urge that the Senate, without delay, ratify said convention, and that Congress make the requisite appropriation to carry the same into effect.

PART I.

SECTION A,

MATHEMATICS, PHYSICS AND CHEMISTRY.

ADDRESS

OF

PROF. H. A. NEWTON,

VICE PRESIDENT FOR SECTION A.

MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:

I THANK you heartily for the honor you have done me in calling me to preside over this section.

The first of the subjects named as belonging to section A, is mathematics. In the few words I shall say, I wish to ask for that branch the real primacy which has thus in form been given to it. I plead for more study of mathematics by American men of science.

I do not speak of its place in education. Whatever interest we may have in schemes of education, we are not discussing them here. That there has been, and is, a notable lack in the amount of American contributions to mathematics has been so fully shown by my predecessor in this office in a recent number of a leading review, that I need not repeat the story.

It is not, perhaps, to be wondered at that in a new country its flora and fauna, its physical and geological features, should have more attraction at first than the exact sciences. Then, too, there have been in this country large rewards to labor, especially to

skilled labor. Livings and prizes have enticed men to work where practical results are directly in view, in the applied rather than in the pure mathematics.

But whether these reasons or others have caused it, the unpleasant fact is that the American contributions to the science of quantity have not been large. Three or four volumes, a dozen memoirs, and here and there a fruitful idea having been selected from them, there is left very little that the world will care much to remember. I refer, of course, to additions to our knowledge, not to the orderly arrangement of it. To make first-rate text-books, or manuals, or treatises, is a work of no mean order, and I would not underestimate it. In good mathematical text-books we need not fear comparison with any nation. But so few additions have been made to our knowledge of quantity, that I fear that the idea has been quite general among us that the mathematics is a finished science, or at least a stationary one, and that it has few fertile fields inviting labor, and few untrodden regions to be explored. Hence many bright minds, capable of good work, have acted as though the arithmetic, the algebra, and the mechanics which they studied covered all that is known of the science. Instead of going on in some path out to the bounds of knowledge, as they had perhaps the ability to do, they dug in the beaten highways, and with care planted seed there, hoping for fruit. How much such ill-directed thought has been spent on the theory of numbers, on higher equations, on the theory of the tides, &c., which if rightly expended on some untrodden though humble field of the science, might have added really to human knowledge! And yet hardly any science can show on the whole a more steady progress, year by year, for the last fifty years, or a larger and healthier growth, than the science of quantity. Here too, as in every other science, the larger the field that has been acquired, the longer its boundary line from which laborers may work out into the region beyond.

An individual may wisely neglect one science, in order to work in another. But a nation may not. For the healthy growth of all, each science should be fostered in its due proportion. But the mathematics has such relations with other branches, that neglect of it must work in time wider injury, I believe, to the cause of science, than neglect of any other branch. I will give a few reasons for this belief.

First, I appeal to your experience. Am I wrong in supposing that

each of you has, at one time or another, been arrested by lack of sufficient knowledge of the mathematics in a line of research that seemed promising? Would not each of you join me in urging a young student in almost any branch of science to acquire first of all such a knowledge of geometry, analysis, and mechanics, that the main ideas in them shall ever be familiar to him, and their processes at need be easily recalled? Certainly so often has the regret of a want of such knowledge been expressed to me by successful men of science, that I have little doubt of your answer.

Again, I argue from a natural law of succession of the steps of discovery in the exact sciences. We first see differences in things apparently alike, or likeness in things apparently diverse, or we find a new mode of action, or some new relation supposed to be that of cause and effect, or we discover some other new fact or quality. We frame hypotheses, measure the quantities involved, and discuss by mathematics the relations of those quantities. The proof or disproof of the hypotheses, most frequently depends upon the agreement or discordance of the quantities. To discover the new facts and qualities has sometimes been thought to be higher work than to discuss quantities, and perhaps it is, But at least quantitative analysis follows qualitative. It is after we have learned *what kind* that we begin to ask *how much*. The investigator is lame if he is not prepared to follow up the discovered relations of the quantities.

Again, throughout the sciences of this section, the laws are more and more assuming a mathematical form. In physics I need hardly mention the increasing rule which rational mechanics is acquiring in reducing classes of phenomena to varieties of forces and motions. In chemistry, mathematical laws must govern the combinations of the elements, both in the processes and in the results of chemical union. Though we may not now explain chemical action as one branch of mechanics, yet the mathematical sciences of heat and light cannot be made complete without extending mathematics over large provinces in chemistry. Even in the sciences of section B, the mechanical and other quantitative ideas are gaining a sure place.

The unwisdom of neglecting the mathematics is again seen by considering some of the problems, which appear to be in their nature capable of a mathematical solution. To explain by the accepted laws of rational mechanics all the forces and motions of the

ultimate particles of matter, of inorganic matter even, may very well be beyond the powers of the human mind. But that some of those forces and motions will be explained, even at an early day, seems to be almost certain. So the essential differences in the chemical elements may not be beyond discovery and explanation. Each line in the spectrum has its definite place, and those places are the results of certain laws of structure of the substance that gives the spectrum, and of its consequent action upon the light that comes from or traverses the substance. The time seems near for a Kepler who shall formulate those laws, and for a Principia which shall unite them in their most general mathematical expression. In like manner along the line that in astronomy and physics separates the unknown from the known, there are hundreds of questions whose solution, if they are to be solved at all, must be in part mathematical.

It is with some hesitation that I leave the more familiar ground of this section and speak of the laws of quantity in the other sciences. But there is good reason apparent to even the outside observer, for the belief that the mathematics will in the future (of course, in some cases, the very distant future) have much to do in fields from which it is now very properly shut out. Indirectly, through physics, it has already a foothold in some of them.

Political economy is in its ultimate nature a branch of applied mathematics, and even in its present condition we are entitled to distrust the guidance in it of one who has not clear conceptions of the relations of quantity. In fact, most of the questions in social science seem to have a two-fold character, the one moral, and the other mathematical. In geology how many problems are rising into importance whose solution depends upon mathematics! The geometry of animal and vegetable forms is a subject as yet almost untouched by the mathematician. Yet in the nature of the case each form is the result of definite forces, and similarity and law in the forms represent like properties in the forces producing them.

There is, moreover, a large possible field of applied mathematics in the science that shall explain the relations between the facts of the outside world and the impressions which they make through the organs of sense on the mind. The Greeks solved practically one of its problems when they made the lines of the Parthenon curved that they might appear straight. Another is met by the astronomer when he has to apply to his own observations a personal

equation. When we can explain the correction which one color needs because of its nearness to another color, we may perhaps have more hope of applying to color a unit of measure, and so treating of its quantity. Music has its mathematical basis, and differences in sounds have submitted to analysis and measurement. The physiological theories of vision and hearing must, as they develop by experiment, furnish many problems to be solved by mathematics.

Even in the sciences beyond the domain of this Association there is some evidence of the sovereignty of number and measure. Some of those who have most thoroughly studied the theory of the beautiful, believe that mathematical laws will yet be found to lie at the basis of that theory. The recognition of a more and a less in all our mental powers, impressions, and actions; of a law of obedience to the strongest motive; of an inseparable connection of the greatest good with right moral action; what are these but the indications of the existence of quantitative laws in mental and moral sciences?

That there is a growing conviction that mathematical relations run through all subjects of thought is proved by the increasing use of the word *force*. Men speak of vital forces, mental forces, moral forces, social forces, force of will, force of passions, of affections, of appetites, force of words, force of public opinion, force of conscience, force of character, and so on, through all the range of thought. The word force can hardly be used, even as a metaphor, without implying, to some extent, the idea of a cause and an effect, each possessing the attribute of quantity, and each related quantitatively to the other, though we cannot in our present ignorance measure the one or the other.

Is all this a mere fancy, or a day-dream of the imagination, rather than a sober conception of science fitted to this occasion? If it so seems to you, look at the actual history of one kind of quantity, that of probability. Quantity of probability differs from most kinds of quantities, in that it is an impression on the mind that has no necessary correspondence with the facts of the outside world. It is, to use the mathematical term, a function of finite knowledge, depending for its magnitude entirely upon what we know, or think we know, changing with every accession of knowledge, real or supposed, becoming certainty in the presence of full knowledge, and having no existence where there is no knowledge at all.

This mental impression of the more and the less probable mathematicians learned to measure. Its theory was first applied to simple games of chance, but it has grown in these two hundred years until it is now the firm basis on which rest pecuniary contracts for many thousands of millions of dollars in insurance. It guides and controls, by the method of least squares, approximate measurements in all branches of exact knowledge, and going over into mental science requires logic to be rebuilt from the bottom.

Has the thought arisen in any of your minds that this idea of a possible extension of the science of quantity is derogatory to those other sciences over whose domains it may some time claim a qualified sovereignty—that it puts the good and the beautiful even alongside of the masses which we weigh and the bulks which we measure? Pure mathematics is not a science of matter. It is a mental science, dealing solely with mental conceptions. I am inclined to accept Prof. Peirce's extension and definition of it, that it is the science that draws necessary conclusions. But however we may extend or limit the science, it expresses necessary laws of our thinking, and it is not derogatory therefore to our highest knowledge that it is made subject to it. Moreover, our conceptions of the Creator become higher, as we are led on by our studies to emphasize the words of the Hebrew wise man, "Thou hast put together *all things* in measure, and in number, and in weight."

PAPERS READ.

On a New Method of Measuring the Velocity of Electricity. By Joseph Lovering, of Cambridge, Mass.

Perhaps it is not too strong a statement to say that a question is half answered when it is properly asked. Now when it is asked, *What is the velocity of electricity*, there is no strict propriety in the question. For electricity has no *velocity*, in the common sense of the word *velocity*. There is no analogy between the transmission of an electrical disturbance and the propagation of light, or sound, or radiant heat, for example. The mathematical theory of the galvanic circuit, as stated by Ohm in 1827, and the more recent analysis on the same subject by Kirchhoff and Sir William Thomson, have appeared to prove that the time of transmission of an electrical disturbance is proportional to the total electrostatical capacity of the conductor, multiplied by its total resistance. As each of these factors increases with the length of the conductor, the time of transmission is proportional to the *square* of the length of the conductor. Therefore, it cannot be told with what velocity electricity will move until it is known through what distance it must travel. If it be asked, not what is the velocity of electricity, but what is its time of transmission, in any particular case, there would be more hope of a definite answer. The distinction just indicated will do much towards reconciling the contradictory results of experiment in regard to what is erroneously called the velocity of electricity; these experiments making the velocity appear to be sometimes as great as 288,000 miles a second, and sometimes no more than 800 miles a second. In the first case the experiment was made on a very short conductor, and in the second case on a conductor of great length.

When experiment undertakes to deal with such amazing rates of transmission as those of light or electricity, one of two things is indispensable; it must possess the means, either of operating over enormous distances of spaces, or of measuring excessively small intervals of time. When the propagation of light is under

consideration, there is a free choice between the two methods. If we choose the first method, which may be called the direct method, astronomy will supply ample spaces, and no extraordinary nicety of measurement in the other elements is demanded. But the practicability of the second method, even when the spaces traversed by the light do not exceed the limits of the physical laboratory, has been demonstrated by Fizeau, Foucault, and Cornu.

If we turn now from the propagation of light to that of electricity, it is obvious that nothing less than the largest lines of telegraph wire furnish the conditions required by the first method. On the 28th of February, and again on the 7th of March, 1869, the late Professor Winlock, of the Harvard College Observatory, sent electrical signals from Cambridge to San Francisco, and thence by other lines to Canada, and back again to Cambridge, over a loop of wire measuring 7200 miles. This long journey was performed by electricity in about two-thirds of one second; and no small portion of this brief interval was lost in bringing into action the thirteen repeaters which were interpolated into the circuit. In the determination of longitude by telegraphic signals, the transmission time of the signals comes out as an incidental result. When the signals are sent eastward, the apparent difference of longitude exceeds the real difference of longitude by the transmission time. When the signals are sent westward, the apparent is less than the true longitude by the same quantity. The average of the two values is the true difference of longitude, and half the difference of the two values is the transmission time of electricity. For example, in the campaign conducted by officers of the United States Coast Survey, in 1869–70, for the determination of transatlantic longitudes, I obtained the following results. The total transmission time between Brest, France, and Duxbury, Mass., by the way of St. Pierre, was ·816 of one second. The total distance by cable is 3329 nautical miles; the distance from Brest to St. Pierre being 2580 nautical miles, and that from St. Pierre to Duxbury 749 nautical miles. When the differences of length, calibre, and materials as between the two branches of the cable are all taken into account, I find that the transmission time between Brest and St. Pierre was ·639 of a second, and between St. Pierre and Duxbury ·177 of a second, so that the two branches were traversed one at the rate of about 4000 nautical miles a second, the other at the rate of 4230 nautical miles a second.

Wheatstone's remarkable experiments on the velocity of friction electricity, first published in 1834, offer an example of the second method of measuring great velocities. In this case, the experiment was made upon a length of only one-quarter of a mile; and the exceedingly small fraction of time required by electricity to traverse this short distance (amounting to only $\frac{1}{1152000}$ of one second) became distinctly measurable by the relative displacement which it produced in the images of two sparks, formed in a rapidly revolving mirror. Hence the hasty conclusion was adopted that the velocity of electricity was 288,000 miles per second. The immense discrepancy between this result and those afterwards reached by experiments on land and ocean lines of telegraph could not be overlooked, and an explanation was sought in the different tensions of friction and voltaic electricity. This explanation was unsatisfactory because direct experiments on telegraph wires appeared to indicate that the velocity of electricity was independent of the strength of the battery. The discrepancy itself vanishes, or changes its character, when attention is given to the law that the transmission time of electricity is proportional to the square of the distance. Wheatstone's experiment simply proved that electricity will go through one-quarter of a mile of wire at the rate of 288,000 miles per second, and that it would pass over only 268 miles of similar wire in one second. Now this is a much *smaller* velocity than is found by experiments on either land or ocean lines of telegraph; the reason being, probably, that in the inferences from Wheatstone's experiment no account has been taken of the intervals of air which separated the different branches of the conducting wire.

The theoretical law, already stated, viz., that the transmission time increases with the square of the velocity, has been verified experimentally by Gaugain. He used two threads of cotton, each of which was 1·65 metres in length. When tried separately, the transmission time on each was eleven seconds. When they were placed end to end, so as to double the length, the time was forty-four seconds.

As Wheatstone's experiment on the velocity of electricity has never been repeated, and as direct experiments upon telegraph lines are not numerous and are not likely to be rapidly multiplied and have not been hitherto very harmonious in their results, some other indirect method of conducting the investigation may be

found of scientific value. For this purpose, I have availed myself of Lissajous' method of compounding the rectangular vibrations of two tuning forks, and amplifying the resultant motion, by the twice reflected beam of light, which afterwards enters a telescope.

The tuning forks and telescope are permanently fixed to a base-board, so as to preserve their adjustment. Each tuning fork is provided with an electro-magnet, in order to maintain its vibration for a long time. The tuning forks, when vibrating independently, are nearly in unison, each making about 128 vibrations in one second. When the electro-magnets are brought into action, by a voltaic current circulating continuously through them and a standard tuning fork, furnished with an electro-magnet and a break-circuit attachment, the first two forks are forced into exact unison with the standard, and, therefore, with each other. Under these circumstances, the resultant orbit seen in the telescope is invariable. If the instrumental corrections for the two electro-magnets are equal, this orbit will be the first of the series for the unison; that is, an oblique straight line. If this is not the case, it will be convenient to make it so, by introducing resistances at the proper place in the circuit. Then, the apparatus is ready to be put to the work of measuring the velocity of electricity. An additional length of resistance coil is introduced, sufficient to change the orbit to some other in the series. The best one to select is the straight line which inclines in the opposite direction. The new orbit proves that one of the forks begins a vibration by half a period behind the other fork; which, in this particular case, is $\frac{1}{256}$ of one second. This fraction of a second is the transmission time for the passage of the current through the additional resistance coil. Unison forks of higher pitch would register smaller fractions of time. So would also forks, in which the ratios of vibration were less simple; but the orbits would be more complex and could not be observed with the same precision as the straight lines.

I have perfected the apparatus, just described, to such an extent as to feel assured of its adaptation to the purpose which has been specified. But I wish to make a larger number of observations, upon different lengths of resistance and under various combinations, before I give numerical results. I propose, hereafter, to subject in this way to experimental trial, the theoretical law that the transmission time increases with the square of the distance,

and that the velocity is inversely as the distance. If this law holds good, the unit time and the unit velocity may be found for a unit distance, or a unit resistance, and then the time and the velocity can be computed for any other distance or resistance. This unit time and unit resistance must be accurately calculated from a combination of all the results of the various experiments. It is also desirable to ascertain the time and velocity for coiled and uncoiled, for naked and covered conductors; as also for air lines and ocean lines. It is to be observed that, in all cases, the time and velocity ascribed to the passages of the electricity apply to that amount of electricity which is required to work the receiving instrument.

On a Method of Exhibiting by Projection the Difference of Velocity of Waves in Various Gases. By T. C. Mendenhall, of Columbus, Ohio.

This arrangement consists of two glass tubes about twenty centimetres in length and three centimetres in diameter, with their ends cemented together with a thin stretched membrane between. In the centre of this membrane is fixed a light style, as a bristle, two or three centimetres in length. This may be put on with a drop of wax before the tubes are cemented together. The outer ends of the tubes are closed with corks through which pass glass tubes one centimetre in diameter, upon which stiff rubber tubes may be slipped. Two such tubes, of convenient length, are attached and their free ends joined in a common chamber, similar to one of the large tubes mentioned above, by means of a cork with two small glass tubes inserted. At the open end of this chamber the disturbance is produced by means of a tuning fork, or simply by a membrane stretched over the end upon which slight taps may be given with the finger. The apparatus is placed before the lantern so that an image of the style is projected upon the screen. Supposing air to fill both tubes it will be seen that an impulse will travel along both tubes and the style be moved in a direction, dependent upon which of the two tubes is the shortest.

When the two waves are transmitted in the same time the membrane will remain at rest. One of the tubes being filled with the gas which is to be compared with air, their relative length is varied until the style is brought perfectly to rest; the waves then reach the opposite sides of the membrane at the same time, and the velocities of transmission will be inversely as the lengths of tube through which the waves pass.

Constructed for use with the lantern the apparatus will necessarily be somewhat coarse in its results. For simply qualitative works it will not even be necessary to resort to any expedient for retaining the two gases in their respective tubes, as in the brief time required for the experiment they will not mix sufficiently to vitiate the results. For more exact results the tube with style may be mounted under a microscope of low power, when the adjustment will be more accurately made. This method is more simple than those of Neumann and Zoch, but is probably not capable of giving equally exact quantitative results.

On the Requisite Amount of Simple Friction of Soft Iron against Cold Steel to Melt it. By B. S. Hedrick, of Washington, D. C.

The development of heat by friction has been long known. For some time it has also been known that the operations of rolling and rubbing had the effect of changing the molecular structure of iron and steel. These operations will toughen and compact cold iron, and will harden and condense steel. Some time since Mr. Jacob Reese, of Pittsburg, Penn., had occasion to construct a machine for cutting bars of cold hardened steel. For this purpose he mounted a disk made of soft wrought iron upon a horizontal axis, so as to be rotated with great velocity. With any moderate speed no cutting was produced. But on giving the disk such a speed of rotation as to cause the periphery of the disk to move with a velocity of about 25,000 feet per minute

(nearly five miles), the steel was rapidly cut, especially when the bar to be cut was slowly rotated against the disk. Sparks in a steady stream were thrown off. At first it was supposed that the steel was simply rubbed or ground off. But on examining the pile of accumulated particles beneath the machine they were found to be welded together in the shape of a long cone, similar to the stalagmites in the limestone caves; they were nearly like the spikes of frost as formed in winter on Mount Washington, and illustrated at the Troy Meeting. Real fusion takes place. The steel is melted by the swiftly-moving smooth edge of the soft iron disk, but the disk itself is but little heated. The bar of steel on each side of the cut receives but a slight heat and the ends are left with a fine smooth blue finish. By this process a rolled, polished, and hardened steel bar of two or three inches diameter, may be cut in two in a few minutes. The soft metal disk of iron used was about forty-two inches in diameter, and three-sixteenths of an inch thick. The particles fly off in a thick jet or stream apparently white-hot, through which the naked hand may be passed without injury, and a sheet of white writing paper held in the stream for a minute is not burned nor colored in the least. They glance off without burning the hand, having assumed the condition which causes the spheroidal state of liquids.

Problems in Watson's Coördinates. By Thomas Hill, of Portland, Maine.

I shall use in the present paper my own modifications of these coördinates, representing a curve by giving the length of a perpendicular let fall from the origin upon the tangent as a function of its direction; that is, $p = f.\, \nu$.

1. The general formulas for transformation of coördinates are

$$p_b = p - b \cos(\nu_a - \beta - a),$$
$$\nu = \nu_a - a, \qquad (1)$$

which serve to transform to a new origin at the distance b and direction β, and a new axis making the angle a with the old one.

2. The equation $p_1 = p + A$ gives by differentiation

$$dp_1 = dp = q_1 = q;\ d^2p_1 = d^2p.$$

and (by Vol. xxii, p. 28, A)

$$\rho_1 = p_1 + d^2p_1 = p + d^2p + A = \rho + A.$$

In other words the addition of a constant to p gives a concentric curve at the distance of that constant from the original curve.

3. The point of equation 5, on the page cited, may then be transformed into a circle with the radius B by writing

$$p = A \sin \nu + B,$$

and the distance A of the centre of the circle may be thrown in any direction from the origin by writing

$$p = A \sin (\nu - a) + B. \qquad (2)$$

4. If the general equation of the circle just given be transformed by equations (1) we may obtain

$$p_1 = A \sin (\nu - a) + B - A \cos (\nu - a - 90^\circ) = B$$

as the equation of the circle referred to its centre.

5. A second transformation will now give

$$p_2 = B - B \cos (\nu - 0) = B (1 - \cos \nu) = 2 B \sin^2 \tfrac{1}{2} \nu$$

as the equation of the circle referred to the right hand point of the locus; which agrees with pp. 28 and 29 in the volume cited.

6. In Vol. xxii, Part I, page 30, I simply say of my fifth problem; "The equation $p = A \nu^n$, n being a positive integer, gives the involutes of a circle."

7. Let now n be either positive or negative of the form $m + \frac{1}{2}$, in which m is integral, and it is easy to see that the curve is one of the involutes, or one of the evolutes, of a curve whose equation is in the form $p = B \nu^{\frac{1}{2}}$; and, if an involute, that the constant of integration has constantly been zero.

8. Differentiating $p = B \sqrt{\nu}$ gives us $q = \frac{B}{2\sqrt{\nu}}$, so that the product pq is constantly $\frac{1}{2} B^2$, and this curve may be defined by that circumstance. In other words the triangle enclosed between r, p, and q is of constant area, and equal to $\frac{1}{4} B^2$.

9. The length of r is found, by squaring and adding, $r^2 = B^2 (\nu + \frac{1}{4\nu})$. This value reduces to a minimum for $\nu = \frac{1}{2}$, when $r = \pm B$; and it becomes infinite for either $\nu = 0$, or $\nu = \infty$. It will be observed that negative values of ν, render the whole imaginary, and are therefore rejected.

10. When $\nu = 0$, $p = 0$, and $q = \infty$; that is, the asymptote passes through the origin at right angles to the axis. But when $\nu = \frac{1}{2}$, $r = B$, (confining our attention to the positive values alone, the negatives simply giving the same curve reversed), and p and q each become $\cdot 707\, B$. That is to say, the curve has come down to a point, whose radius vector is B, and direction from the origin is $\frac{\pi}{4} + \frac{1}{2} = 73° \; 38' \; 52''\cdot 4$.

11. When ν increases beyond the value $\frac{1}{2}$, it is evident that r constantly approximates in its value to that of p, while q approximates towards zero. This second part of the curve, therefore, as it recedes from the origin, is asymptotic to a spiral of which the polar equation would be $r = B\sqrt{\varphi}$, which is in fact described by the foot of the perpendicular p, at its meeting with the tangent.

12. The curve may then be conceived as generated by the end of a perpendicular raised at the end of the radius vector, $r = B\sqrt{\varphi}$, and of the length $\frac{B}{2\sqrt{\psi}}$,—the general mode of plotting in these coördinates.

13. The curve may also be conceived as generated by the corner of a rectangle of constant area ($\frac{1}{2}B^2$), revolving around its opposite corner, and varying in such manner as to make one of the adjacent sides tangent to the curve. The adjacent corner of the rectangle on the tangent then describes the spiral $r = B\sqrt{\varphi}$, asymptotic to the second part of the curve, while the fourth corner describes a lituus asymptotic to the first part.

14. The equation of the lituus in polar coördinates is, $r = \frac{B}{2\sqrt{\psi - \frac{\pi}{2}}}$, or taking the asymptote as axis $r = \frac{B}{2\sqrt{\psi}}$.

15. If the fundamental curve be considered in its reverse order, and the generating point be considered as approaching the origin

on the second part and receding on the first, the motion will more strongly suggest the name of Tantalus.

16. The radii of curvature and radii vectores are readily found as follows:

$$\text{For the tantalus, } r = B\sqrt{\nu + \tfrac{1}{4\nu}};\ \rho = \tfrac{B}{4}\left(\tfrac{4\nu^2 - 1}{\nu\sqrt{\nu}}\right).$$

This value of ρ shows that there is a cusp at the point of nearest approach to the origin.

$$\text{For the spiral, } r = B\sqrt{\varphi};\ \rho = \frac{B}{2\sqrt{\psi}} \cdot \frac{(4\psi^2 + 1)^{\frac{3}{2}}}{4\psi^2 + 3}.$$

$$\text{For the lituus, } r = \frac{B}{2\sqrt{\psi}};\ \rho = \frac{B}{\sqrt{\psi^3}} \cdot \frac{(4\psi^2 + 1)^{\frac{3}{2}}}{4\psi - 1^2}.$$

This value of ρ shows that the point of contrary flexure in the lituus corresponds to the cusp of the tantalus, and occurs when the rectangle of Art. 8 becomes a square. No singularity is manifest in the spiral at the corresponding point.

17. The angle which the curves make with the radius vector being called ϵ, we have

For the tantalus, $tan\ \epsilon = 2\ \nu$,
For the spiral, $tan\ \epsilon = 2\ \varphi$,
For the lituus, $tan\ \epsilon = 2\ \psi$.

18. The points at which the second part of the tantalus intersects the first part may be found by substituting $2\ n\ \pi$ for a in the value of ν,

$$\nu = \tfrac{1}{4}\left(\tfrac{1 - 4a^2}{2a} + \sqrt{4a^2 + 2}\right),$$

in which the single sign is placed before the radical for the reason given in Art. 9.

19. The equations of Art. 17 show that the sides of the rectangle make the same angle with the lituus and spiral, that its diagonal makes with the tantalus.

20. The triple generation of Art. 13 may be otherwise defined by making one corner of a rectangle of constant area, move in the lituus, or in the spiral.

21. In Problem I of the paper above cited, in which $sin\ a\ \nu$ is used for ν, I discussed only integral powers. Let us now take the equation $p = \sqrt{A\ sin\ a\ \nu}$.

22. This gives us

$$q = A\,\frac{a \cos a\,\nu}{2\sqrt{\sin a\,\nu}};\ r = A\,\frac{\sqrt{(4-a^2)\sin^2 a\,\nu + a^2}}{4 \sin a\,\nu}$$

$$\rho = \frac{(4-a^2)\sin^2 a\,\nu - a^2}{4\,(\sin a\,\nu)^{\frac{3}{2}}};\ \tan \varepsilon = \frac{2}{a}\tan a\,\nu.$$

23. These values show us that two asymptotes pass through the origin, one at right angles to the axis, the other making an angle with the axis equal to $(\frac{1}{a} - \frac{1}{2})\,\pi$.

The values of r and ρ also show that there are in general two cusps, and minimum values of r when $\sin a\,\nu = \left(\frac{4}{a^2} - 1\right)^{-\frac{1}{2}}$. As the sine is limited to unity, these cusps disappear when a exceeds $\sqrt{2}$.

24. The values of p and r exclude values of ar which come in the third and fourth quadrants from consideration. In the following paragraphs I will also omit the consideration of the negative values of p and r.

25. For $a = \frac{1}{2}$, the cusps are at the points $\nu = 29° 56'$, $\varepsilon = 46° 54'$, $\varphi = 73° 2'$, and $\varphi = 286° 58'$ and $r = A \cdot 7034$, while the asymptotes coincide, or rather are opposite to each other. The cusps are connected on the left by two-thirds of an oval, in the loose sense of that word.

26. For $a = 1$, the asymptotes coincide, and for the cusps we have, $\nu = 35° 15'$, $\varepsilon = 54° 43'$, $\varphi = 70° 32'$, $r_1 = A\sqrt{\frac{1}{2}\sqrt{3}}$.

27. For $a = \frac{4}{5}$, the second asymptote makes an angle of 55° with the axis and the cusps correspond to $\nu = 42° 33'$, $\varepsilon = 64° 8'$, $\varphi = 68° 25'$ and 75° 35′. The asymptotic branches cross at a point for which $\nu = 72°$, and as a is enlarged, the cusps approach each other, until

28. When $a = \sqrt{2}$ the cusps meet and disappear, and the curve becomes quasi-hyperbolic.

29. For the case $a = 2$ the equations readily are reduced, by vol. xxii, 28 A, to rectangular coördinates; giving $xy = \frac{1}{2}A^2$; which is the equation of an equilateral hyperbola.

30. When $a > 2$, the second asymptote, by article 23, makes a negative angle with the axis; the magnitude of which is limited to $-\frac{1}{2}\pi$. When $a = \infty$ and the second asymptote takes this limiting position, p fluctuates between the values A and 0; q fluctuates between 0 and ∞; while the naso, if I may so name the curve, is a straight line parallel to the two asymptotes, fluctuating in position between coincidence with them, and recession to the distance A.

31. If p and p_1 are reciprocal, we have, by vol. xxii,

$$p = f\nu,\ q = Dp,\ r = \sqrt{p^2 + q^2},\ tan\ \varepsilon = \frac{p}{q},\ cot\ \varepsilon = D\ log\ p,$$

$$p_1 = \frac{1}{p},\ q_1 = \frac{-q}{p^2},\ r_1 = \frac{r}{p^2},\ tan\ \varepsilon_1 = -\ tan\ \varepsilon.$$

In other words, if $p = p_1^{-1}$, then the triangles, whose sides are pqr and $p_1 q_1 r_1$, are for any value of ν, similar, and symmetrically disposed on the line p.

32. Let $p = \sqrt{c^2 \sin^2 \nu + B^2}$.

Then $\rho = p + D^2 p = \dfrac{C^2 B^2 + B^4}{(C^2 \sin^2 \nu + B^2)^{\frac{3}{2}}} = \dfrac{B^2 (C^2 + B^2)}{(C^2 \sin^2 \nu + B^2)^{\frac{3}{2}}}$,

which shows the curve to be an ellipse whose principal semi-axes are $\sqrt{C^2 + B^2}$ and B; and the distance apart of its foci is $2\ C$.

33. The rotation of the last curve through 45° gives the equation

$$p = \sqrt{\tfrac{1}{2}\ C^2\ (1 + \sin 2\nu) + B^2},$$

and if B^2 be now made negative and equal to $\frac{1}{2}\ C^2$ this reduces to the naso of article 29.

34. The equation $p = \sqrt{A \sin a\ \nu + B}$ readily yields us

$$\rho = \frac{A^2\ (4 - a^2)\ \sin^2 a\ \nu + 2\ A\ B\ (4 - a^2)\ \sin a\ \nu + B^2 - A^2\ a^2}{4\ (A \sin a\ \nu + B)^{\frac{3}{2}}}.$$

35. When $a = 1$, and $B = A = C^2$, these equations reduce to the forms

$$p = C\sqrt{(1 + \sin \nu)}\ = C\ (\cos \tfrac{1}{2}\ \nu + \sin \tfrac{1}{2}\ \nu)$$

$$\rho = \tfrac{3}{4}\ p \quad , \qquad r = \tfrac{1}{2}\sqrt{3\ p^2 + 2},$$

which are manifestly equations of an epicycloid of two cusps, referred to the centre of the stationary circle, and with the axis passing through the cusps.

36. The equations which Dr. Watson gave, at the meeting in 1859, for caustics by reflection, require a little modification when p is taken as I propose. Let $p = f.\, \nu$ be the equation of a curve when referred to an axis parallel to parallel rays of light, and $q = D_\nu\, p$. The equation of the caustic $p_c = f_c .\, \nu_c$ will then be obtained from the following, which are manifest from the geometry of the problem:

$$p_c = q.\, cos\, \nu - p.\, sin\, \nu;\ \nu = \tfrac{1}{2}\nu_c - 45°.$$

37. For caustics from diverging rays let $p = f.\, \nu$ be the equation of a curve when referred to the radiating point as origin. Then geometrical examination gives at once, if we use η for $\frac{1}{2}\pi - \epsilon$,

$$p_c = r\ sin\ 2\ \eta = r\ sin\ 2\ \epsilon;\ \nu_c = \nu + \epsilon.;\ \nu = \nu_c - \epsilon.$$

38. For an example in article 36, take

$$p = B, \text{ which gives } q = 0,$$

$$p_c = -B\, sin\, \nu = -B\, sin\, (\tfrac{1}{2}\nu_c - 45°) = -\frac{B}{\sqrt{2}}\, (cos\, \tfrac{1}{2}\, \nu_c + sin\, \tfrac{1}{2}\, \nu_c\,),$$

which is, as in 35, the epicycloid that it should be.

39. For an example in article 37 take the spira mirabilis

$$p = e^{a\nu}, \text{ which gives } cot\ \epsilon = a,\ sin\ 2\epsilon = \frac{2a}{1 + a^2}$$

$$r = \sqrt{1 + a^2}.\, p = \sqrt{1 + a^2}.\ e^{a\nu_c - a\, cot\, a}$$

$$p_c = \frac{2a}{\sqrt{1 + a^2}e.^{arc\ cot\ a}}\, e^{a\nu_c}$$

which is Bernouilli's theorem that the caustic is a precisely similar spira mirabilis.

A Systematic Method for indicating the localities of a Country, and for Rapidly Discovering Places on a Map by means of Letters or Symbols attached to the Names of Places (copyright secured). By J. M. Toner, of Washington, D. C.

ABSTRACT.

While making some geographical studies requiring a definite knowledge of localities and the fixing of them upon a map, I was struck with the defects of all the systems known to me to facilitate this kind of work. The best of them wastes time to a degree that

the busy student cannot afford. A re-reference to a place consumes as much time as the original search. Over two years ago I adopted the plan here set forth, and exhibited in the coloring of the map of the United States.

My suggestion is to divide a country, a nation, or a state, into nine divisions in the following manner. Taking our own country: —First, to divide the United States as nearly as possible from east to west into three equal divisions, then from north to south the same; this order of division it will be seen, with the angles, gives a section for a central and all the cardinal points of the compass, by which name I now would designate them.

In dividing the United States, or, any country, I would preserve the boundaries of states, provinces, or territories, and in dividing a state preserve the civil divisions of county lines. Having done this, collect the names of all the localities embraced in each section, and attach to each its appropriate symbol, then arrange them all in alphabetical order. The list is then ready for use. This has been done for the states within the United States and is exhibited on the left hand margin of the large map. In designating states the letters have been used that are employed to designate the points of the compass. An example of the application of this principle to counties within states, is given on the margin of the map of Ohio and Indiana, also exhibited. In designating counties a symbol has been used instead of a letter, the point indicating the section. For divisions within a county I have adopted a circular symbol with a point, as in the square, used to designate the localities of counties. The symbol should be of the size of ordinary type and set up on the line just after the name of a county or town.

The advantage gained by this system is, that the moment the eye rests upon the name of a place, the symbol is also seen, which conveys at the same time definite information as to locality. This concurrent mental impression is of great value and must always accompany the reading of the name that has a symbol. It is rather to the system of indicating localities that I wish to call attention than the particular division represented upon the accompanying maps. Others may prefer a different grouping of the states. The division to some extent is an arbitrary one. The alphabetical list of states with the letter indicating the point of

the compass prefixed, cannot fail to suggest the section to which each belongs.

STATES.		STATES.	
S.	Alabama.	S.	Mississippi.
N.W.	Alaska.	C.	Missouri.
S.W.	Arizona.	N.W.	Montana.
C.	Arkansas.	C.	Nebraska.
W.	California.	W.	Nevada.
W.	Colorado.	N.E.	New Hampshire.
N.E.	Connecticut.	E.	New Jersey.
N.	Dakota.	S.W.	New Mexico.
E.	Delaware.	N.E.	New York.
E.	District of Columbia.	E.	North Carolina.
S.E.	Florida.	E.	Ohio.
S.E.	Georgia.	N.W.	Oregon.
N.W.	Idaho.	E.	Pennsylvania.
C.	Illinois.	N.E.	Rhode Island.
C.	Indiana.	S.E.	South Carolina.
C.	Indian Territory.	C.	Tennessee.
C.	Iowa.	S.	Texas.
C.	Kansas.	W.	Utah.
C.	Kentucky.	N.E.	Vermont.
S.	Louisiana.	E.	Virginia.
N.E.	Maine.	N.W.	Washington.
E.	Maryland.	E.	West Virginia.
N.E.	Massachusetts.	N.	Wisconsin.
N.	Michigan.	N.W.	Wyoming.
N.	Minnesota.		

The same may be said of the divisions of states into sections to classify the counties. [An alphabetical classification of the counties of Ohio with the symbols annexed was exhibited. The application of the principle of designating localities within a county, where a circle is used instead of a square, was also exhibited.]

The convenience and the utility of this method for the schoolroom, the counting-house, as well as for the general reader will, I apprehend, be appreciated without a further exposition of the system.

On some Inequalities of Long Period in the Moon's Motion. By John N. Stockwell, of Cleveland, Ohio.

If we denote the mean and true longitudes of the moon as seen from the centre of the earth by nt and v, and the mean and true distances of the moon from the same point by a and r; and also neglect the eccentricity and inclination of the moon's orbit in the coefficients of the disturbing function, the general differential equations of motion will give, supposing the sum of the masses of the moon and earth to be denoted by μ

$$\frac{dv}{dt}=\frac{\sqrt{a\mu}}{r^2}\left\{1-\frac{1}{\sqrt{a\mu}}\int\left(\frac{dR}{dv}\right)dt\right\}, \qquad (1)$$

$$\left.\begin{aligned}\frac{dr}{dt}=\frac{\cos nt}{\sqrt{a\mu}}\int&\left\{-a^2ndt\cos nt\left(\frac{dR}{dr}\right)+2andt\sin nt\left(\frac{dR}{dv}\right)\right\}\\ -\frac{\sin nt}{\sqrt{a\mu}}\int&\left\{a^2ndt\sin nt\left(\frac{dR}{dr}\right)+2andt\cos nt\left(\frac{dR}{dv}\right)\right\}\end{aligned}\right\}(2);$$

in which the functions $\left(\frac{dR}{dr}\right)$ and $\left(\frac{dR}{dv}\right)$ denote the negative of the disturbing forces in the direction of the radius vector and perpendicular to the radius vector in the direction of the moon's motion.

Now the general terms in the development of the disturbing forces may be expressed by equations of the following forms.

$$\left(\frac{dR}{dr}\right)=m\cos(\beta\, nt+at+\theta),\ \left(\frac{dR}{dv}\right)=m'\sin(\beta' nt+a't+\theta'), (3)$$

in which m and m' are constant coefficients depending on the mass of the disturbing body and on the mean distances, eccentricities and inclinations of the orbits; β, β' are whole numbers or nothing; a, a' are coefficients depending on the longitude of the sun and on the positions of the perihelia and nodes of the two orbits; and θ, θ' are arbitrary constant quantities which serve to make the equations satisfy any required conditions.

If these general values of $\left(\frac{dR}{dr}\right)$ and $\left(\frac{dR}{dv}\right)$ be substituted in equations (1) and (2) they will give,

$$\frac{dv}{dt}=\frac{\sqrt{a\mu}}{r^2}\left\{1-\frac{m'\cos\theta'}{\sqrt{a\mu}\,(\beta'n+a')}+\frac{m'}{\sqrt{a\mu}\,(\beta'n+a')}\cos(\beta'nt+a't+\theta')\right.; (4)$$

$$\left.\begin{aligned}\frac{dr}{dt}=&-\frac{a^2 n m\,(\beta n+a)}{\sqrt{a\mu}\,(\beta n+n+a)\,(\beta n-n+a)}\sin(\beta nt+at+\theta)\\ &+\frac{2a\,m'\,n^2}{\sqrt{a\mu}\,(\beta'n+n+a')\,(\beta'n-n+a')}\sin(\beta'nt+a't+\theta')\end{aligned}\right\} (5)$$

Equation (5) gives by integration

$$
\begin{aligned}
r = a\Big\{1 &- \frac{a\,n\,m \cos\theta}{\sqrt{a\mu}\,(\beta n + n + a)(\beta n - n + a)} + \frac{a\,n\,m}{\sqrt{a\mu}\,(\beta n + n + a)(\beta n - n + a)} \cos(\beta n t + a t + \theta) \\
&+ \frac{2\,m' n^2 \cos\theta'}{\sqrt{a\mu}\,(\beta' n + n + a')(\beta' n - n + a')(\beta' n + a')} \\
&- \frac{2m'\,n^2}{\sqrt{a\mu}\,(\beta' n + n + a')(\beta' n - n + a')(\beta' n + a')} \cos(\beta' n t + a' t + \theta')\Big\}
\end{aligned} \tag{6}
$$

It is evident that this solution fails for the particular case in which $a' = 0$, and $\beta' = 0$; because the last two terms would in that case become infinite. It would also become inaccurate for that class of inequalities which arise solely from the variation of the elements of the earth's orbit. The case in which $a' = 0$, $\beta' = 0$, evidently corresponds to the motion of a body in a circular orbit through a resisting medium of uniform density, which would produce a constant negative tangential force. The case also of a tangential force arising from the variation of the eccentricity of the earth's orbit, would also be comprised in the general form $a' = 0$, $\beta' = 0$; and we shall give a special development of formulæ for these two cases.

For inequalities of long period $\beta = 0$, $\beta' = 0$, and a, a', are incomparably smaller than n, as it is then independent of the sun's longitude, and is simply a function of the variations of the elements of the orbits of the sun and moon.

If we therefore put $\beta = 0$, $\beta' = 0$, $n \pm a = n$, and $n \pm a' = n$, in equation (6) it will become

$$
\left.\begin{aligned}
r = a\Big\{1 &+ \frac{a\,m\,n}{\sqrt{a\mu}\,n^2} \cos\theta - \frac{a\,m\,n}{\sqrt{a\mu}\,n^2} \cos(at + \theta) \\
&- \frac{2m'}{\sqrt{a\mu}\,a'} \cos\theta' + \frac{2m'}{\sqrt{a\mu}\,a'} \cos(a't + \theta')\Big\}
\end{aligned}\right\}, \tag{7}
$$

If we substitute this value of r in equation (4) it will become

$$
\frac{dv}{dt} = \frac{\sqrt{\mu a}}{a^2}\Big\{1 - \frac{2a\,m}{n\sqrt{a\mu}} \cos\theta + \frac{3m'}{a'\sqrt{a\mu}} \cos\theta' + \frac{2a\,m}{n\sqrt{a\mu}} \cos(at + \theta) - \frac{3m'}{a'\sqrt{a\mu}} \cos(a't + \theta')\Big\}. \tag{8}
$$

If we put $n = \frac{\sqrt{a\mu}}{a^2}$, equation (8) will give by integration,

$$
\left.\begin{aligned}
v = nt\Big\{1 &- \frac{2a^2\,m}{\mu} \cos\theta + \frac{3a\,m'\,n}{\mu\,a'} \cos\theta'\Big\} + \frac{2a^2\,m\,n}{\mu\,a} \sin(at + \theta) \\
&- \frac{3a\,m'\,n^2}{\mu\,a'^2} \sin(a't + \theta').
\end{aligned}\right\}. \tag{9}
$$

If we now substitute the values of m, m', and also the corres-

ponding values of a, a', θ and θ', we shall obtain the expressions for the inequalities of long period (properly so called), depending on those arguments. Equation (9) will also give the values of the secular inequalities arising from the secular variations of the central force; but for secular variations of the tangential force m', the expression would become inaccurate by reason of the extreme smallness of the division a', as already observed.

We will now illustrate the use of formula (9), by some applications to inequalities in the moon's motion that are well known to astronomers. For this purpose we shall observe that the analytical development of the function $\left(\frac{dR}{dr}\right)$ gives the following term $-\frac{3}{4}\frac{\overline{m}^2}{a^2}e'^2$, e', being the eccentricity of the earth's orbit, which is variable from the action of the other planets. This term may be reduced to the same form as equations (3), by putting $e'^2 = h \cos (at + \theta)$, in which h, a and θ are constant. There are no corresponding terms in the development of $\left(\frac{dR}{dv}\right)$. We must therefore put $m = -\frac{3}{4}\frac{\overline{m}^2}{a^2}h$, and $m' = 0$, in equation (9), and it will then become

$$v = nt\left\{1 + \frac{3}{2}\frac{\overline{m}^2}{\mu}h\cos\theta\right\} - \frac{3}{2}\frac{\overline{m}^2 n}{\mu a}h\sin(at+\theta). \quad (10)$$

In order to reduce this formula to numbers, we must know the values of h, a and θ, which depend on the variation of the eccentricity of the earth's orbit; and also the values of $\overline{m}^2$ and n.

Now I find that e'^2 is very accurately given by the following formula

$$e'^2 = 0{\cdot}000406774 \cos (9''.8865{\cdot}t + 46^\circ\ 15'\ 11''{\cdot}7), \quad (11)$$

in which t denotes the number of Julian years from 1850; t being negative for times preceding that epoch. This very simple value of e'^2 will give the actual value of the eccentricity at all times during a period of 5,000 years, antecedent to the epoch of 1850, with as much precision as the ordinary development of the same quantity in an infinite series, when the series is extended so as to include terms depending on the fourth power of the time. Now $\overline{m}^2$ denotes the product of the sun's mass by the cube of the ratio of the moon's distance to that of the sun. Reduced to numbers it becomes, log. $\overline{m}^2 = 97.7532136$. Equation (10) will therefore become, by using for n the value of the moon's mean motion in a

Julian year, and transforming the last term so that it shall become equal to nothing when $t = o$, as follows,

$$v = nt - 40''.90028.t - 1706628'' \sin \tfrac{1}{2} at \cos \tfrac{1}{2} at + 1782968'' \sin^2 \tfrac{1}{2} at. \quad (12)$$

If in this we substitute the value of a, and also make $t = \pm 200$, we shall obtain the amount of the secular inequality during a period of 200 years before or after 1850, and we shall find, for $t = -200$, $v = nt + 40.''70$, and for $t = +200$, $v = nt + 41.''12$, which values would correspond to a coefficient of about 10.″23 for the first century before or after the epoch.

Since $e'^2 = h \cos \theta$, at the epoch, it is evident that the term, $\frac{3}{2} \frac{\overline{m}^2 n}{\mu} h \cos \theta$, represents the whole effect of the eccentricity of the earth's orbit on the moon's mean motion at that epoch. Now this mean motion would be constant provided that e'^2 were constant; but it is evident that if e'^2 were variable by the quantity $\Delta e'^2$, the mean motion of the moon in a Julian year would vary by the quantity $\frac{3}{2} \frac{\overline{m}^2 n}{\mu} \Delta e'^2$. If we now suppose that $t = -50$ in equation (11), we shall find $\Delta e'^2 = 0.000000703431$; and substituting this value in the preceding term we shall find that the variation of the mean motion between the beginning and middle of the present century amounts to 0.″1022869. As this is the variation of the mean motion in fifty years, if we multiply it by 100, we shall have the whole effect of the variation of the eccentricity of the earth's orbit on the moon's longitude during the first century preceding 1850, equal to 10.″22869, a quantity closely approximating to the early determinations of the value of the secular inequality.

Let us now apply the same formula to the investigation of the inequality of long period in the moon's mean motion depending on the action of *Venus*, or rather to that part of it which arises from the variation of the elements of the earth's orbit depending on the same cause, and which has already been discussed by Hansen, Delaunay and Newcomb. Taking the data given by Airy and Pontécoulant, I find that the expression of the radius vector of the earth's orbit contains the term $+ a' [92.39127] \cos at$, the coefficient in brackets being a logarithm, and a being equal to eight times the mean motion of *Venus* minus thirteen times the mean motion of the *earth*. The term of $\left(\frac{dR}{dr}\right)$ will therefore be-

come $\frac{3}{2}\frac{\overline{m}^2}{\mu a^3}$ [92.39127], and log. $a = 96.49564$. It is evident that $\left(\frac{dR}{dv}\right)$ does not contain any similar term, when the direct action of the planet on the moon is neglected. We must, therefore, put $m' = 0$, and m equal to the above term of $\left(\frac{dR}{dr}\right)$, and we shall obtain $\Delta v = + 0.''2723 \sin(at + \theta)$, a value identical with that obtained by Delaunay, as quoted by Airy, in *Monthly Notices of the Royal Astronomical Society* for November, 1873.

As a third example I will now attempt the computation of the inequality of long period, depending on the sun's action, and which has for the argument, the double of the longitude of the node of the lunar orbit plus the longitude of its perigee, minus three times the longitude of the sun's perigee. The value of the coefficient of this inequality has never been computed, so far as I am aware, and it is an object of importance to determine it.

The whole difficulty in determining the value of the inequality consists in finding the coefficients of cos $(3\omega' - \omega - 2\Omega)$, in the value of $\left(\frac{dR}{dr}\right)$, and the coefficient of the sine of the same angle in the value of $\left(\frac{dR}{dv}\right)$. The computation of these coefficients is a matter involving great labor, and I can here give only a general indication of the method employed, and the various steps of the process.

The argument of this inequality arises from the development of the term $\frac{15}{8}\frac{r^3}{r'^4}\cos^3\theta\cos 3(v - v')$, in the expression for $\left(\frac{dR}{dr}\right)$; and also from the term $\frac{15}{8}\frac{r^3}{r'^4}\cos^3\theta\sin 3(v - v')$, in the value of $\left(\frac{dR}{dv}\right)$; and the coefficient contains the product of the factors $e\,e'^3\gamma^2$. Therefore, in the computation of this coefficient, we need take into consideration only the following terms of the expressions of r, r' and θ; namely:

$$r = a\,\{1 - e\cos(nt - \omega)\},$$
$$r' = a'\,\{1 - e'\cos(n't - \omega') - \tfrac{1}{2}e'^2\cos 2(n't - \omega') - \tfrac{3}{8}e'^3\cos 3(n't - \omega')\},$$
$$\cos\theta = 1 + \tfrac{1}{4}\gamma^2\cos 2(nt - \Omega) - \tfrac{1}{2}e\gamma^2\cos(nt + \omega - 2\Omega) + \tfrac{1}{2}e\gamma^2\cos(3nt - \omega - 2\Omega);$$

and also the terms containing the corresponding powers of e, e' and γ, in the expression of the angle $3(v - v')$. It should be observed that θ here denotes the latitude of the moon.

Now it is convenient to divide the process into two parts, as follows: We must first form the products of the three factors $\frac{r^2}{r'^4}\cos^3\theta$, and $\frac{r^3}{r'^4}\cos^3\theta$, which will consist of about fifty terms, each having different arguments and coefficients. In the formation of the products we must reject all the terms which would have e^2 or γ^4 for a factor, but we must retain all the terms containing either of the first three powers of e'. These products being formed we must then develop the *sine* and *cosine* of $3(v-v')$, retaining all the terms having similar powers of e, e' and γ. The development of these terms is much more laborious and extensive than that of the other factor, and comprises about two hundred terms, having coefficients greater than $ee'^3\gamma^2$. Then in multiplying these developments together we need retain only the terms having arguments in which the mean motions of the sun and moon enter with the same combinations; the formation of the product will then eliminate the mean motions and leave the argument depending only on the variation of the elements. For example, we shall find that the development of the term $\frac{r^3}{r'^4}\cos^3\theta$ gives the term $-3e\cos(nt-\omega)$, and that of $\sin 3(v-v')$, gives the term $+\frac{3}{2}e'^3\gamma^2\sin(nt-3\omega'+2\Omega)$. The product of these two terms will then give the term $+\frac{9}{4}ee'^3\gamma^2\sin(3\omega'-\omega-2\Omega)$. We shall also find that we have the terms, $+\frac{63}{64}e'^2\gamma^2\sin(nt-n't-2\omega'+2\Omega)$, and $6\,ee'\cos(nt-n't-\omega+\omega')$; and the product of these gives the term $+\frac{189}{64}ee'^3\gamma^2\sin(3\omega'-\omega-2\Omega)$. And by carefully comparing the developments of the two factors, we shall find that there are sixteen terms in each, having arguments and coefficients which, by combination, will produce the preceding equation of long period; and if we put the sum of these terms for the perturbing function, we shall find,

$$\left(\frac{dR}{dr}\right)=-\frac{26595}{512}\frac{\overline{m}^2}{a'}ee'^3\gamma^2\cos(3\omega'-\omega-2\Omega),$$

and $$\left(\frac{dR}{dv}\right)=-\frac{6885}{512}\frac{\overline{m}^2}{a'}ee'^3\gamma^2\sin(3\omega'-\omega-2\Omega).$$

The development of the process, just explained, has been made with great care, and I have considerable confidence in the correctness of the results obtained; but on account of the intricacy of the subject, the development ought to be repeated in detail by some other person, and the results compared.

If we now put $m = -\frac{26595}{512}\frac{\overline{m}^2}{a'}ee'^3\gamma^2$, $m' = -\frac{6885}{512}\frac{\overline{m}^2}{a'}ee'^3\gamma^2$, and $a = a' = 3\omega' - \omega - 2\Omega = -0{\cdot}0004064235.n$, in equation (9), we shall obtain $+0.''0016$ for the value of the coefficient arising from the variation of the central force, and $+1.''5356$ for the coefficient depending on the tangential component of the disturbing force.

It may excite remark that the tangential component of the disturbing force, which is only about one-fourth part of the radial disturbing force, should nevertheless produce an effect on the moon's longitude almost one thousand times greater. This arises from the fact that the terms of perturbation arising from the tangential forces, by means of the double integration receive the square of the coefficient of t in the expression of the argument as a divisor; whereas the terms of the longitude arising from the perturbing force in the direction of the radius vector, notwithstanding they also suffer two integrations, only acquire the first power of this coefficient as a divisor, and for this reason it acquires only an insensible value. Putting the two coefficients together we get $1.''5372 \sin(3\omega' - \omega - 2\Omega)$ for the inequality of long period due to the sun's action and depending on the proposed argument. This quantity is hardly of sufficient magnitude to be of much importance in the present state of the lunar theory; and yet it is large enough to make it desirable to have the whole calculation repeated with great care, inasmuch as a mistake in the sign of some of the numerous terms of which its coefficient is composed, would be sufficient to give it a coefficient large enough to make it an important element in the theory of the moon's motion; and I most earnestly hope that some abler mathematician than myself may be induced to repeat the whole investigation.

We have already remarked that equations (6) and (9) fail to give accurate results for the particular case in which $a' = 0$, because the coefficients depending on this quantity then become infinite. In order to develop formulæ for this particular case we shall resume the consideration of equations (1) and (2); and shall suppose that $\left(\frac{dR}{dr}\right) = 0$, and $\left(\frac{dR}{dv}\right) = m'$. Equations (1) and (2) will then give, m' being constant,

$$\frac{dv}{dt} = \frac{\sqrt{a\mu}}{r^2}\left\{1 - \frac{m'}{\sqrt{a\mu}}.t\right\}; \qquad (13)$$

$$\left.\begin{aligned}\frac{dr}{dt} &= \frac{\cos nt}{\sqrt{a\mu}}\int 2\,a\,m'\,ndt\ \sin nt - \frac{\sin nt}{\sqrt{a\mu}}\int 2\,a\,m'\,ndt\ \cos nt \\ &= -\frac{2\,a\,m'}{\sqrt{a\mu}}\left\{\cos^2 nt + \sin^2 nt\right\} = -\frac{2\,a\,m'}{\sqrt{a\mu}}\end{aligned}\right\}. \quad (14)$$

Equation (14) gives by integration,

$$r = a\left\{1 - \frac{2\,m'}{\sqrt{a\mu}}.t\right\}. \qquad (15)$$

This equation shows that a constant positive tangential force continually increases the radius vector, while a constant negative tangential force, which would result from the motion of a body in a resisting medium of uniform density, would in like manner perpetually decrease the radius vector. The effect of a resisting medium in the planetary spaces would therefore have a tendency to decrease the mean distances of the planets from the sun and from each other.

If we now substitute the value of r given by equation (15), in equation (13), it will become

$$\frac{dv}{dt} = \frac{\sqrt{a\mu}}{a^2}\left\{1 + \frac{3\,m'}{\sqrt{a\mu}}.\,t\right\} = n + \frac{3\,m'\,n^2\,a}{\mu}.\,t. \quad (16)$$

This equation gives by integration

$$v = nt + \tfrac{3}{2}\,\frac{m'\,n^2\,a}{\mu}.\,t^2. \quad (17)$$

If the tangential force, $-m'$, is positive it produces a retardation of the moving body, and a contrary effect if the tangential force is negative.

To leave no doubt on this important point we shall give the following additional demonstration. If we neglect the inclination of the orbit, the general equation which expresses the relation between the variation of the mean distance and the forces producing the variation, is the following:

$$d\,\frac{\mu}{a} = 2\left(\frac{''}{dr}\right)dr + 2\left(\frac{dR}{dv}\right)dv; \quad (18)$$

and if we consider the effect of only the tangential force $\left(\frac{dR}{dv}\right) = m'$, and also suppose that the mean distance and mean motion at the epoch are denoted by a_o and n_o, equation (18) will give

$$da = -\,2a_o^{\,2}\,\frac{m'}{\mu}\,dv = -\,2a_o^{\,2}\,\frac{m'\,n_o}{\mu}\,dt. \quad (19)$$

Equation (19) gives by integration

$$a = a_o\left\{1 - \frac{2_o a\,m'\,n_o}{\mu}.\,t\right\}. \quad (20)$$

Now since the mean motion at any time is equal to $\frac{\sqrt{\mu}}{a^{\frac{3}{2}}} = n$, equation (20) will give $n = n_0 \left\{1 + \frac{3a_0 m' n_0}{\mu} . t\right\}$. (21) Multiplying this equation by dt and integrating we get

$$v = \int n dt = n_0 t + \tfrac{3}{2} \frac{m' n_0^2 a_0}{\mu} . t^2, \qquad (22)$$

which is identical with equation (17), already found by a different method, since a_0, n_0 are equal to a, n, respectively, at the epoch. It is but proper to observe that equations (17) and (22) may be deduced from the general value of v given in equation (9), by developing sin $(a't + \theta')$, and afterwards putting sin $a't = a't$, and cos $a't = 1 - \frac{1}{2} a'^2 t^2$.

If we now suppose that $m' = \pm \frac{3}{4} \frac{\overline{m}^2}{a} \Delta e'^2$, $\Delta e'^2$ denoting the variation of e'^2 during half a century, equation (17) or (22) will give

$$v = nt \pm \tfrac{9}{8} \frac{\overline{m}^2}{\mu} \Delta e'^2 n^2 t^2. \qquad (23)$$

Reducing this formula to numbers it becomes $v = nt \pm 6.''4438 \cdot t^2$, t denoting the number of Julian years. Therefore a constant tangential force, which is equal to the change of the central force, arising from the variation of the eccentricity of the earth's orbit during fifty years, would produce a secular equation amounting to $\pm 64438''. i^2$, in which i denotes the number of centuries before or after the year 1850. The magnitude of this equation shows how extremely sensitive the moon's motion is to the influence of forces of this character; and if we compare it with the equation resulting from an equal central force, we shall perceive that a positive tangential force which is equal to the *six-thousandth* part of the central force which produces the acceleration, would have the effect to neutralize the inequality produced by this latter force, and the moon's longitude would always remain the same as if neither disturbing force existed.

If the tangential force were negative, which would be the case if it were produced by a resisting medium, the moon's longitude would be continually increased and its distance from the earth would perpetually decrease from the operation of this cause.

In conclusion we may observe that La Place has shown (*Mécanique Céleste*, book II, chapters VII and VIII) that there can be no terms of the form we have here considered, when the mean motions of the bodies of the system are incommensurable with each other;

and the subject has been introduced here for the purpose of showing that an inconceivably small force of the character here considered would be extremely sensitive in its effect on the moon's motion, and it was desirable to ascertain the possible effects of such forces, inasmuch as the opinion is held by some astronomers that the secular equation in the mean motion of the moon is modified to an important extent by forces of the same character.

ON A NEW METEOROLOGICAL INSTRUMENT. By J. W. OSBORNE, of Washington, D. C.

THE study of Meteorology has always possessed great attractions for those investigators who desire rapid practical results for the aid and benefit of mankind.

Of scientific men there has been a large proportion, both workers and theorizers, who have labored in this field; but it is chiefly of late years that great and important advances have been made. Not only have the means of observing atmospheric phenomena been improved, but the observations themselves have been systematically extended over vast tracts of country, and have, by the help of the telegraph, been collected with such rapidity, as to greatly increase their scientific as well as practical value. Great results have been the legitimate consequence of the large expenditures of labor and money which such records demand; results which have been appreciated by the general public, and still more thoroughly by scientific men; and which would now be very unwillingly dispensed with by either class. But it will be seen that these facts, however valuable and important, are all of an essentially objective character. We are informed both for the past and future respecting atmospheric pressure, and temperature; of the direction and force of the wind; of the relative quantity of moisture present, and of the amount of rain,—in a word, of all the available facts, external to the earth we stand on, and to our own bodies, which scientific and material resources can supply. These things have a bearing upon our comfort and prosperity; they affect

us as merchants, traders, agriculturists and manufacturers; and the information is conveyed in a form directly applicable to our wants; but we do not, procure from such statements, any distinct or precise knowledge of the manner or the degree in which they affect us personally.

It is hardly too much to assert that, at the present day, after years of laborious research, the meteorologists furnish no data from which it is possible to deduce the subjective character of any given climate, or its effect upon the human body. We might go farther and say—of life upon the face of the earth.

This is certainly true if we seek for a numerical expression which shall make possible the comparison of the climate of one place with that of another; or of the same place at different times of year; or the climate of indoors with that of the open air; for we cannot grasp in a single expression the several meteorological elements affecting us, referred as each is to a totally different unit of measurement. Considerations like the foregoing have caused me to attempt the construction of an instrument which would furnish the information sought, or such an approximation towards it, as would add definitely to our knowledge, and lay a foundation for future developments in this direction.

Confining myself at present to considerations affecting the human body, I will preface the description of the instrument itself, by drawing attention to the following facts.

If an effort is made to realize the nature of the influence which the elements exert upon the body of a man, it will appear that the prominent and leading effect they tend to bring about is a change in his temperature. This, for certain of the meteorological elements, may be either a raising or a lowering of the bodily heat; but taken together, their joint and total effect must tend at all times, and in every habitable climate, to dissipate and reduce the normal heat of the body.

If this were not so, the oxidation within the organism would cause an increase in the temperature of the blood and viscera, thereby establishing a state of things inconsistent with health, and with life itself, for any length of time. It must not be lost sight of, therefore, in considering this subject, that the body of a living healthy man is a mass of hot matter, cooling, and having its lost heat perpetually supplied by physiological changes, in quantity sufficient to maintain a uniform thermal standard of about 98½° F

And, whatever the causes of this loss may be, we say when it is rapid that the weather is cold, and when slow that it is hot. In the one case, the functions are called upon to make up the deficiency rapidly, and in the other to facilitate the dispersion of the body's superfluous and injurious warmth.

The temperature, as shown by the thermometer, is very commonly, I might almost say universally, accepted, as indicating the thermic influence acting upon us, and we speak of its readings as if they expressed in some way the sensible temperature with which the living organism has to deal. That this is an error, and a very pernicious one, a moment's reflection will serve to show. The day is hot and oppressive, if, at 80° F., the air is damp and still; while with a breeze and dry atmosphere, it is fresh and pleasant. Or, if in winter the thermometer fall to 20° F., no inconvenience is felt so long as it is perfectly still; but should it blow hard, then the cold will be almost unendurable.

Accordingly, what I shall call the physio-thermal effect, appears to be the joint result of several influences, acting simultaneously, each affecting in variable degrees, and often in contrary ways, the rate at which the body cools.

The three great factors which together determine the sensible climatic heat, are the temperature of the air at the time; the relative amount of aqueous vapour present; and the force or velocity of the wind. The first acts by accelerating or retarding, and sometimes altogether neutralizing radiation from the hot human body. The second, that is the moisture, promotes or hinders evaporation from the skin and lungs, in variable degrees, determining in like proportion the consequent loss of heat. The wind acts in two ways; first, as a convector, it removes from the body with greater or less rapidity the warmed film surrounding it, bringing cooler air in its place to be warmed up again in its turn; this action being of course reversed in those cases where the external temperature is above $98\frac{1}{2}$° F.: and secondly, for a similar reason, the wind acts in all cases as a promoter of evaporation (except when perfectly saturated with moisture at or above the temperature of the surface of the body), the refrigeration bearing some relation to the rate at which it travels.

The problem I have sought to solve then is, to furnish means by the help of which we may express numerically and comparably that which hitherto has been left to vague conjecture and state-

ment, namely: the aggregate of the physio-thermic influences which affect the living human body at any particular time and place.

Without going into minute details, the instrument I have invented is constructed as follows.

A pole, or standard about six feet high, made of a strong brass tubing, is held upright by a heavy foot or base.

At right angles from this, and in the same direction, three arms or brackets extend. These, while they slide up and down on the standard, can be clamped at such places as suit the height of the observer.

The middle bracket is nine or ten inches long, and carries at its outer extremity a horizontal cylindrical ring of thin brass about four inches in diameter.

From the lower edge of this ring, and held fast to it by a strong rubber band or clamp-ring, there hangs a cylinder made of "bond," or bank-note paper. This cylinder is exactly 100 millimetres in diameter, and 150 long. It is made upon a turned mandrel, and closed up the side by the use of a thick mucilage of albumen, dried, and then coagulated by immersion in wet steam. This method gives a very narrow, strong seam, which absorbs water like the rest of the paper.

Into the open bottom of the paper cylinder a very thin disk of brass is fitted, and held there by a second rubber band or clamp-ring.

The vessel so constructed is intended to hold water. The paper which forms its walls can be removed and replaced at any time, without altering its capacity, or the relation between its bulk and surface. The upper edge of the brass ring, from which the paper cylinder hangs, is provided with a flat brass cap. Through the centre of this a short tube or socket extends. This revolves in the cap, fitting into a suitable bearing for that purpose. It terminates above in a small horizontal pulley, with a hole through its centre, while to its lower end an agitator is attached.

The agitator consists of a narrow strip of thin metal formed into a spiral, which makes four revolutions from the top to the bottom of the cylinder. When this is made to rotate, it sweeps the inside surface of the paper cylinder, but without touching it. From the brass disk below, three vertical stationary blades, placed radially, rise to the level of the top edge of the paper. These blades leave

still an unoccupied space in the centre of the cylinder; and between their outer edges and the paper, the spiral revolves freely. The object of the blades is to hold the water contained in the cylinder from revolving, so that the spiral, when in motion, may cause a constant current down the inside surface, and up the centre of the cylinder. The lower of the three brackets carries at its extremity an upright, adjustable, slender pin of wood, which fits easily into a little projecting socket attached to the centre of the under side of the disk, which forms the bottom of the cylinder, and prevents the paper suffering from lateral impulses given it by the wind, or when it is being moved from place to place.

The upper bracket carries a thermometer on its outer end. This is exactly over the axis of the cylinder, so that when it is lowered, the bulb, which extends seven or eight inches below the scale, passes through the horizontal pulley and short tube connecting it with the agitator, and takes its place in the centre of the mass of water, in which position it is clamped. This thermometer is provided with a centigrade scale. Its tube is ground flat, and polished on two opposite surfaces parallel to the ribbon of mercury. The scale to which it is attached is pierced by a narrow slit which extends from zero upwards to 100°. By this means I succeed in getting rid of the reflection from the cylindrical surface of the tube, and can watch the column of mercury as it appears projected against a little white screen adjustable behind the scale. A sliding cross hair parallel to the lines of division on the scale, and supported about an inch in front of the latter, is also used to fix the position of the eye when reading, and so avoid parallax. This slide is connected with a long screw at the side of the scale, by revolving which it can be placed and held in any required position.

For very exact readings a microscope with cross hair is also employed, which then takes the place of the simple slide just described.

A clock-work, attached to the standard below the brackets, imparts motion to a small silken belt which runs upwards in a vertical plane as far as the middle bracket, where two little rollers give it a lateral direction, so as to drive the horizontal agitator-pulley, and thereby keep the contents of the cylinder in a thoroughly mixed and moving condition, that the temperature of any part may be always that of the whole.

Below the clock-work a vessel of thin brass is supported by a

short arm. This is somewhat larger in size than the paper cylinder; it fills a double purpose, acting as a covering for the cylinder when not in use, and receiving the overflow water from it in a manner to be presently described.

A fourth bracket or arm, which may be regarded as supplemental to the instrument proper, is clamped at a convenient height on the central standard. It extends in an opposite direction from the other three, and carries the ordinary wet and dry bulb thermometers, and a stop watch with a spring-back second hand.[1]

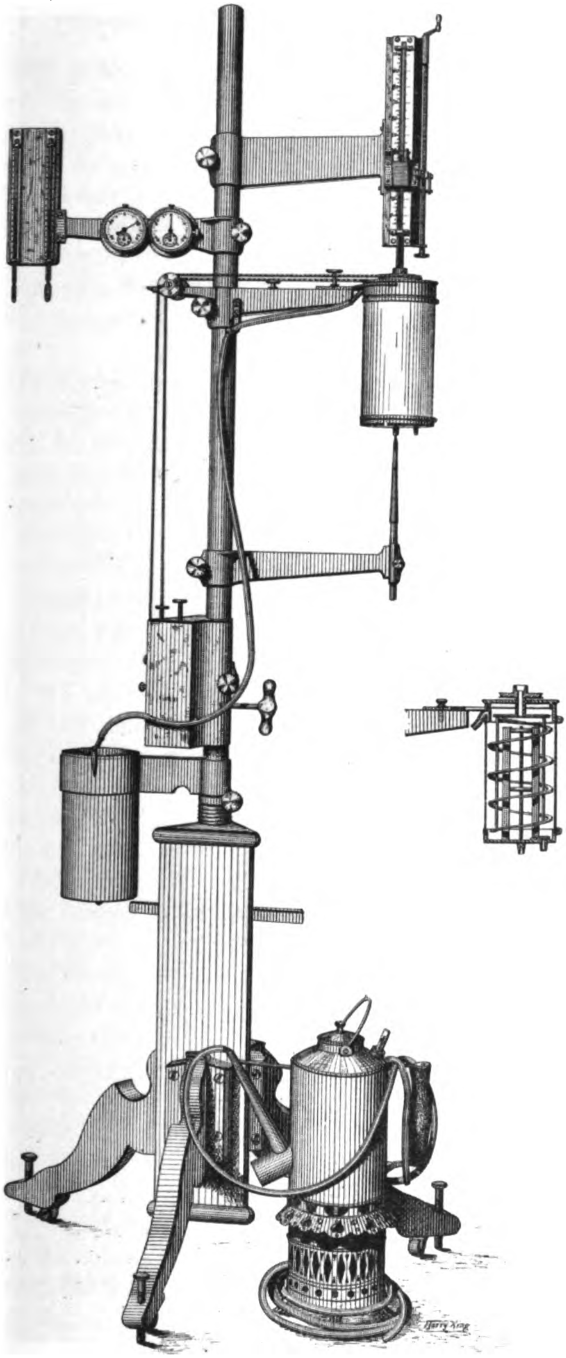
Lastly; a high copper vessel called the filler, holding about two quarts of water, with a long curved spout tapering down to $\frac{1}{4}$ inch diameter, is used for filling the cylinder with hot water.

This filler is furnished with a cover, and a wooden handle opposite the spout; it is also provided with a thermometer which is slipped into a small dry tube extending from the top obliquely towards the centre of the vessel, so that while the water in it is heating on a gas stove, its temperature can at any time be ascertained approximately.

I proceed now to explain the way in which observations are taken with this instrument. The cylinder above described is a porous vessel. Its bond paper walls are slowly permeable to water, so that without appearing wet on the outside, they offer to the air as much moisture as it is capable of taking up; that which is lost being quickly replaced by capillary action. Experiment so far has shown this to be the case, except when the evaporation is very excessive indeed. The bond paper by its strength, and the purity of its composition, and from the fact that it can be obtained of perfectly uniform character, is admirably adapted for this purpose; and when wet it looks and feels very like an animal membrane. I know of no material of constant quality, and one which could be made into a vessel of a definite and fixed size, that would answer as a substitute for it.

If the suspended cylinder so constructed be filled with water at the temperature of the blood, it will be seen that its condition is similar to that of a man who has lost the power of generating

[1] In the drawing which accompanies this paper, two stop-watches are shown instead of one, by which the timing of sequent intervals is much faciliated. Both watches are connected by a brass strap in such a way that the movement which stops one starts the other instantly. The spring-back arrangement is independent of this, so that each reading is made from zero, with plenty of time for its exact registration.



[illegible]

heat. Both will instantly begin to fall in temperature. Now if we could ascertain the time in which the man's body fell one degree, we would be justified in assuming that when he was in the normal condition he would have had to make the same amount of heat in a like interval, inasmuch as he always has to make exactly what is lost.

Strictly speaking, a little more would be demanded of him, because the hotter his body is, the more heat he will lose in a given time. For very small increments however, this difference may be neglected, and I will not at present discuss it.

This interval of time then, would express the demand upon the system, the intensity of the physiological action necessary to sustain the body in a state of health; and it would also be a measure of the climate at that particular time and place, subjectively considered. As such a determination for the actual man is impossible at present, I endeavor to obtain a comparable result from the cylinder. Assuming it to be full of cold water, as is generally the case, its temperature is raised by slipping a piece of small rubber tubing over the spout of the filler, the contents of which have been previously heated several degrees above blood-heat, and attaching the other end of it to a little conical tube which passes through the thin brass disk, forming the bottom of the cylinder. This tube is flush on the inside, and is closed there by a small flap of thin rubber, so that the water cannot flow outwards. By raising the filler above the level of the top of the cylinder, the hot water lifts the valve and enters. As it rises, it fills a small siphon tube, which passes through the side of the brass ring from which the paper hangs, and then flows off through a rubber tube to the overflow vessel, near the foot of the standard, which has been already described.

At the commencement of this operation the clock-work is set in motion, whereby the agitator is made to rotate, and establish so perfect a mixing of the hot and cold water as to cause the temperature to rise gradually and steadily; the addition of hot water can then be checked, and the rubber tube removed, at any particular position of the mercury. After this has been done, the siphon still continues to act, until the water is finally cut off exactly at the upper edge of the paper, by which the quantity of water in the cylinder is always precisely the same.

Having raised the temperature of the whole mass of water dis-

tinctly above blood-heat (37° C.), and letting the agitator continue uninterruptedly, the observer waits till the mercury falls to 37° C., when he starts the stop watch, and counts the time in seconds which each degree takes to fall, till he has obtained a series sufficiently long to give the character of the descent, and render a reduction to a single expression possible. In summer weather about six readings will probably be found sufficient; in winter a greater number may often be desirable. The whole interval which elapses from first to last, should be long enough to allow of several repetitions of the cycle of fluctuations in the thermic influences, which the observer will soon recognize, so that an average result may be had. When a series of this kind is made under constant conditions (as for instance in a closed room) a perfectly smooth and regular curve will be the result; but this is not easily obtained, because of the difficulty of maintaining such conditions perfectly. In the open air the changes in the velocity of the wind invariably give rise to irregularities with which the mathematician will have to deal. These irregular oscillations coincide exactly with the gusts of wind, and the comparatively still intervals between them; they coincide also with the observer's sensations of coolness and warmth.

The general character of these curves is much influenced by the position of the wet bulb temperature in relation to 37° C. When these are near each other, the cylinder will cool slowly, and the curve will be flat; when the temperature of evaporation is low, the fall will be rapid, and the curve proportionately steep. That this must be so will be recognized at once, when it is remembered that the ordinate coinciding with the temperature of the wet bulb must be regarded as an asymptote to the curve.

No earnest attempt has yet been made to determine the equation of these curves. Indeed there has not been time, nor a sufficient number of satisfactory observations made under constant conditions; but as an expedient for present use and instruction, I devised the following method, by which to obtain comparable reductions which should furnish values proportional to each other.

If, under constant influences we extend the readings upwards from 37° C., beginning to time the fall of the thermometer at say 60° C., we shall find that the curve at such high temperatures differs very little from a straight line.

If we regard it as such, and select say 50° C., as the point of

comparison, we shall obtain readings from which it is easy to eliminate the irregularities due to wind, or any other intermittent causes. Thus, if the day is very warm the observer begins to time the descending mercury at 53° C., and counting till it reaches 3° below 50, namely 47° C., he divides the total number of seconds by 6. This interval in the hottest and most sultry weather will be about 5 minutes. If the day is cooler, judging by his feelings, the observer may fix on 4° above and 4° below dividing by 8; if quite cold 10° above, and 10° below, and even double that will not be too much, always aiming at a total interval of about 5 minutes.

It will be seen that the colder the weather is, the more nearly will the curve about 50° C. approach a straight line, and the further below that temperature will it retain the same character, so that the error will not increase with the longer distance travelled by the mercury. This method is based upon the assumption that the ordinates of the normal curve are proportional, and that an arithmetical mean will therefore reduce them, however irregular, to a single expression.

It may be urged that results so obtained are disassociated from the blood temperature with which we started; but it should not be forgotten that we do not aim to get absolute, or even relative values. The great difference in men's weight, and surface in relation to their weight; in the amount of clothing they employ; in their habits of body, and in many other ways, renders that impossible. All we can hope for are results which shall be themselves proportional, and comparable only as regards the average man.

With this in view one temperature is theoretically as good as another, although in the practical use of the instrument, and in the application of corrections, which have yet to be investigated, a judicious selection may be made. Nor should it be thought that I regard the observations at high temperatures, as replacing the series at low ones, which give us the special character and fluctuations of the thermic influences. The latter are of the greatest importance, and throw much light both on the nature of the climate, and on the physiological power of resistance to its influence, which the body is called upon to exert. In this connection it may be well to say something of the dimensions given for the present to the cooling vessel. Numerous experiments have been made with cylinders of different capacity, and with large differences in the relation of mass to surface. The result reached appears to

be tolerably satisfactory and serviceable; but it cannot be regarded as fixed; nor is it possible by *a priori* reasoning to establish any size as the best. The conditions to be kept in view are, first:— To see that the rate of cooling is not disproportionately influenced by any one of the three factors. Second: to give the cylinder sufficient mass to ensure readings of suitable duration. Third: to make the instrument as a whole convenient and manageable, in a mechanical sense. To discuss this subject fully, more information is required than I possess at present.

Having done something towards arriving at a knowledge of the aggregate of physio-thermic influences which the temperature of the air, its moisture, and its motion jointly exert; our next effort should be to analyze that aggregate, if possible, and apportion to each factor its share, positive or negative as the case may be, in the abstraction of animal heat.

If we observe with two cylinders at the same time, which are identical in every respect, save that one is pervious, and the other impervious to water, the results will differ, that from which there is no evaporation taking longer to cool than the other. This difference will express the value of the aqueous vapor present, as a cooling agent.

If simultaneous observations are made with two instruments, one exposed to the full force of the wind, and the other sheltered from it, but otherwise under the same conditions, we shall in like manner get an expression of the thermic influence referable to the wind, both as a convector and as a promoter of evaporation.

If both cylinders are impervious to water we shall again eliminate evaporation and obtain the cooling effect of the dry air in motion.

If from the aggregate effect of all the factors, we now deduct that due to the moisture, and to the wind, the remainder will be the thermic influence ascribable to the actual temperature alone.

There may be, and doubtless are, many and serious difficulties to be overcome in making these determinations; but that the knowledge I have indicated in the foregoing, will eventually be obtained, there is little doubt, as there can be none of its great importance and value to mankind.

One step more it will then be fair to demand; I mean the discovery of empirical formulæ, by which meteorological observations already made and recorded may be converted into expressions of

thermic influence. In this way a vast flood of light will be quickly thrown on questions relating to the influence of climate on conditions of health and disease; development and decay; mental energy; and subjects of like immediate personal interest.

To speak of results at this time, and obtained from an instrument but a few months in existence, would certainly seem premature; and yet some things have been so forcibly presented to my mind, that a very short statement of them may be permitted. The consecutive, outdoor observations I have made consisted of two daily, at 7.35 A. M., and at 4.35 P. M., synchronous with those of the signal service observatory. These have been prosecuted for a little more than two months.

The deductions which they certainly justify are as follows:—

1. That the sensible temperature affecting us departs widely from the actual, obtained from the thermometer.

2. That the fluctuations in it are infinitely greater in amount than most of us have any idea of.

3. That besides the great changes from day to day in the mean sensible temperature, we have what may be called instantaneous oscillations, also very considerable in amount, and scientifically all but unknown.

4. That the wind very often plays a more important part in determining the sensible temperature than the actual temperature itself.

5. That the instantaneous oscillations are almost solely due to fluctuations in this meteorological element.

The first statement I have already illustrated by an example, which might be supplemented by a multitude of others; for nothing is more common, while the thermometer is always quoted as something which cannot err, than to hear people praise or blame the weather quite irrespective of the teachings of that instrument, and often in direct contradiction to them. We use in fact in ordinary conversation a number of phrases which show the necessity in the popular mind of qualifying the information furnished by science. We speak of hot weather as sultry, close, heavy, dull, muggy, and clammy; or as fresh, pleasant, and clear. Of the cold days as raw, bitter, or damp, and also as fresh, bright, and invigorating.

We describe a locality as exposed and bleak; or as sheltered and warm. A house as drafty; a street as "shut in." We say

that not a breath of air is stirring; meaning really that we feel the want of some cooling agent, and for relief we fan ourselves to "get air." All such qualifying words give vague expression to phenomena which figures do not reach.

With regard to the wide range of the sensible temperature it may be said that the difference in the rate at which we lose heat, on a still, hot, and moist day in August or September, and on a cold one in midwinter, with the mercury below zero, and a gale of wind blowing, is very great indeed, subjecting the bodies of all exposed animals to extremes of heat and cold of which the physiologists have taken but little account. Still less have they recognized the existence of instantaneous oscillations. As we sit in our rooms, every breath of air which enters lowers the sensible temperature, and every moment of calm raises it immensely; an incessant rise and fall which may take place several times a minute.

To illustrate the importance of the wind as a thermic agent, the assertion may be ventured, that there are many wet, stormy climates, such as that of Ireland, where it scarcely freezes, that will be found, so far as our bodies are concerned, to approach the still, cold climate of the icy north.

In the foregoing I have made no reference to the direct, radiant heat from the sun; nor has anything been said of the thermic influence on vegetable life. These subjects are of very great importance, but their discussion can perhaps be better undertaken at a future time.

It should not be thought that in pursuing the present inquiry, I have ignored the other influences which climate exerts upon man; acknowledging those only that manifest themselves by sensations of heat or cold. This is not the case; but I do maintain that such appear to our present view as by far the most important, as well as the most amenable to investigation.

I earnestly desire the coöperation of others in developing the untrodden field which forms the subject of this paper. Everything in my power which can aid any one wishing to prosecute similar observations, shall be done with the utmost heartiness. Work of this sort is arduous and exacting, and until it is taken up by many persons, its progress will be slower than its importance demands.

IOWA COUNTY METEOR. By N. R. LEONARD, of Iowa City, Iowa.

THE Iowa County Meteor fell on the evening of Feb. 12, 1875, at about a quarter past ten o'clock, local time. The fall was accompanied by a brilliant light, and by heavy detonations, which in some places were sufficiently violent to shake houses and create in the minds of many an apprehension that an earthquake was in progress. Owing to the general clearness of the sky, the meteor was seen over a wide extent of country; the region in which it was visible being at least 400 miles long, from southwest to northeast, and 250 miles in breadth. It apparently attained its maximum of brightness when about sixty miles from the place where it struck the earth, at which time it was described as glowing with an intense white light, more brilliant than the moon; the color toning down successively to yellow and finally to red, when it disappeared near the town of South Amana, a railroad station in Iowa County.

On the third day after the fall, a fragment weighing seven pounds six ounces, was found lying on the snow, about three miles southeast of South Amana. It was slightly adherent to the snow and ice underneath, and an examination of the ground plainly showed that it had first struck the earth a little more than thirty feet in a direction nearly southwest from where it was found. Soon after the snow melted away, in the latter part of March, other pieces were found, some larger than the first one, others smaller, until, at this date, the sum total amounts to more than 500 pounds. The general appearance of these fragments will be seen from the two specimens which are here before us. The first one shows an unusual number of the different features presented by the different fragments.

I will call your attention to three of these features.

First: You will see a great many short, minute, and parallel ridges on its surface, which have apparently been left by the melted matter as it flowed backward. From an examination of these ridges, we would naturally conclude that the fragment was not, at the time of their formation, moving forward by a whirling or revolving motion, but with a certain definite point in front; and you can see on the edges farthest from this point, where the flowing matter poured over the edge, and formed a little incrusted ridge back of these edges.

Second: There are places along some of these edges where the fragment has evidently parted with some small spawls of its original mass, and over the fresh surfaces thus formed you will see a secondary coating which obviously consists, in part, of molten matter from the surface in front of it, and which ran back over it and appears as if pasted upon it.

Third: There is an elevated, slightly interrupted ridge, surrounding the fragment, a sort of beaded circlet if you please, which appears to consist of molten drops of nickeliferous iron. I have secured a number of specimens marked in a similar manner, and I find that each circlet lies nearly in a plane. In one case there is a fresh fracture of the specimen running across this plane, and the position of the plane can be traced across the fresh surface by the occurrence therein of unusually large particles of nickeliferous iron. The want of homogeneous structure within is here traceable upon the outer surface. This also shows that the iron in these fragments has a tendency to be aggregated in certain planes, thus leading to inquiries which should be first of all referred to the Chemist for quantitative examination; and to the Physicist it presents the question: Under what conditions could this mass have taken its present form?

The second specimen shows three faces that are covered with the secondary coating. I will say here, that out of perhaps 100 different fragments of this meteor in my collection, by far the larger part are almost entirely covered with what you may call the primary coating, and where it appears (by means of a secondary coating), that a part of the original mass was broken off, it is generally but a small part that constituted a salient point.

It is not evident to me, after a somewhat careful examination of more than half the whole mass found, that these fragments were ever united in one solid body. They do not seem capable of being fitted accurately together. Neither is there an apparent difference in the thickness or character of the coating on the different faces which would lead me to think that some were originally on the outside, and that the others were formed at a later period by explosion.

The region over which the meteorites were scattered is about seven miles long by four miles in its greatest breadth. Those fragments which fell toward the southern end of this field were nearly all quite small, and the largest piece yet formed weighing

seventy-four pounds, lay at the extreme north of this field. Owing to the frozen condition of the ground and the low angle of descent, there were but few cases where the meteorites imbedded themselves in the earth.

In endeavoring to compute the path of the meteor, I found such a wide discrepancy in the observations furnished, that I have felt obliged to confine my attention to those only which were so definite, and made under such circumstances as to admit of careful verification and measurement afterwards. Such observations could only be obtained from those who are somewhat accustomed to observe, and who had the good fortune to see the meteor pass by some recognized point, from which the observer stood at a known distance and direction. From observations of this character, I have been able to determine with a fair degree of accuracy, I think, four points in the meteor path.

The observations upon which I have relied, were made by Messrs. E. H. Warrall, C. E., of the U. S. Corps of Engineers, stationed at Keokuk, Iowa. Prof. J. K. Macomber, of Iowa, Agricultural College, and Mr. F. Christen, of Amana, Iowa County.

In addition to these data which were given after careful instrumental measurements of Azimuth and Altitude, I have used two *estimates* of elevation for the purpose of determining the *course* the meteor was pursuing. These estimates were made at a distance of sixty miles south of the place where the meteor fell, one upon the east side and the other upon the west of the path. I have visited the observers who furnished these estimates, and going with them to the point of observation, had them point out for me the elevation at which it passed them. Although sensible that their recollection in this respect may be at fault, I think that the natural overestimate of altitudes, is probably nearly the same in both cases. And still farther, the location of the observers and the nature of the problem is such, that a small variation in this respect would not change materially the value of the thing sought.

The course of the meteor thence deduced was from southwest to northeast at an angle of 18° with the meridian, a result which satisfies such other tests as I have been able to apply to it. This course can be laid down upon a map of Iowa, by drawing a line through a point three or four miles east of the city of Ottumwa, and thence to a point about one and a half miles east of the town of South Amana.

The height of the meteor at different distances from the point where the largest fragment fell is as follows:

At 68	miles	S.W.	according	to observation at	Keokuk	15	miles.
" 38	"	"	"	"	Ag. Coll.	12	"
" 22	"	"	"	"	Amana	8	"
" 2	"	"	"	"	"	2+	"

Several of these measures are closely approximated by calculations founded on *estimates* of elevation furnished by different persons.

The velocity with which the meteor path was described cannot be definitely determined by any data in my possession. I will give such approximations as they furnish.

Mr. Warrall, who saw it, describe about fifty miles of its path, gave the time as five seconds.

Mr. Ream of Oskaloosa, gave the time of the last thirty-five miles as from ten to twenty seconds. Mr. Donnell of Sigourney, gave ten seconds for the same distance. Prof. Macomber gave three to four seconds for the twenty or twenty-five miles preceding the explosion. Mr. Christen, who observed it through the last sixty or seventy miles, gave the time as ten to twelve seconds. The last estimate of time is pretty well substantiated by the distance walked by Mr. C. during the time. Probably the average velocity of the last fifty miles of its path was not above six or seven miles per second.

On the Distribution of the Asteroids. By Daniel Kirkwood, of Bloomington, Indiana.

Nearly twenty years since, when the number of known asteroids was less than fifty, it was inferred from physical considerations that great irregularity must obtain in the distribution of these bodies, and that gaps or chasms would be found in those parts of the zone where the periods of asteroids would be commensurable with that of Jupiter. To verify this theory every addition to the group was watched with interest. In 1866, when

the number had increased to eighty-eight, the agreement between theory and observation had become so marked that I ventured to call attention to the fact in a paper read at the Buffalo meeting of this Association. The comparison of fact and hypothesis has been continued to the present time; the latest summing up of results having been made at the Indianapolis meeting in 1871. Within the last four years thirty-one members have been added to the cluster; and it is now proposed to show that these recent discoveries, more clearly than ever, illustrate the truth of the theory suggested in 1866.

The difference between the greatest and least mean distances is 1·28, and as 146 members of the group are now known, a uniform distribution would give 0·0088 as the average interval between consecutive orbits. The entire zone contains the following distances at which the periods of minor planets would be commensurable with that of Jupiter: —

(1.)	3·27;	where 2	periods	would	be equal	to 1	of	Jupiter.
(2.)	2·25;	" 7	"	"	"	2		"
(3.)	3·47;	" 11	"	"	"	6		"
(4.)	2·50;	" 3	"	"	"	1		"
(5.)	3·02;	" 9	"	"	"	4		"
(6.)	2·95;	" 7	"	"	"	3		"

Now, when the members of the group are arranged in the order of their mean distances, it is found that the widest intervals are at the distances above given. Thus

At 3·27	the interval is	0·1628, or 18	times the mean.
" 2·25	"	0·0632, or 7	"
" 3·47	"	0·0620, or 7	"
" 2·50	"	0·0577, or 6½	"
" 3·02	"	0·0573, or 6½	"
" 2·95	"	0·0566, or 6	"

It seems impossible to regard the foregoing as casual coincidences. I have elsewhere assigned a physical cause for the facts observed — a cause believed to be adequate both in mode and measure.

Of the thirty-one asteroids discovered during the last four years but one, according to the published elements, is found in a gap

previously indicated. This is No. 139, which is assigned by the elements of Doolittle and Wilson[1] to that portion of the zone in which five periods would be equal to two of Jupiter. If these elements are correct, the period of this asteroid has the same ratio to that of Jupiter that the latter has to the period of Saturn. As the observations, however, from which the planet's elements were derived, extended only from the 10th to the 17th of October, the mean distance given may be considerably modified. In this case the chasm remaining about the distance 2·82 will be five times greater than the mean interval.

The marked irregularity in the distribution of asteroids throughout the zone is presented at one view in the following table:—

Interior to the distance 2·26	. . .	2	asteroids.
from 2·26 to 2·36	. . .	7	"
" 2·36 to 2·46	. . .	25	"
" 2·46 to 2·56	. . .	5	"
" 2·56 to 2·66	. . .	20	"
" 2·66 to 2·76	. . .	28	"
" 2·76 to 2·86	. . .	13	"
" 2·86 to 2·96	. . .	4	"
" 2·96 to 3·06	. . .	4	"
" 3·06 to 3·16	. . .	13	"
" 3·16 to 3·26	. . .	5	"
" 3·26 to 3·36	. . .	0	"
Exterior to 3·36	. . .	4	"

In three portions of the ring the clustering tendency is here distinctly evident. These are from 2·36 to 2·46, from 2·56 to 2·76, and from 3·06 to 3·16. We have thus an obvious resemblance to the rings of Saturn; the partial breaks or chasms in the asteroid zone corresponding to the well known intervals in the system of secondary rings.

It is a remarkable fact in the development of the solar system that the largest planet, Jupiter, should be succeeded by a space so nearly destitute of matter as the zone of asteroids; the ratio of the masses being that of 1 to 5180.[2] An explanation of this

[1] *Astr. Nach.*, No. 2030.

[2] Adopting Alexander's mass of the Asteroids. See Smithsonian Contributions to Knowledge, No. 280, p. 33.

striking disproportion was suggested in the Proceedings of the American Philosophical Society, for August 19, 1870. In view of the facts above presented, however, it seems pertinent to ask, What *would have been the results* of Jupiter's influence on the zone, had the density of the latter been equal to that of other planetary rings?

As the periodic time of nebulous masses at the distance 3·27 from the centre of motion was precisely one-half that of Jupiter, the influence of the exterior planet would give increasing eccentricity to their orbits. The disturbed matter would, therefore, be brought into contact, either with exterior parts of the ring, in aphelion, or with interior portions, in perihelion. A number of planetary nuclei would thus be formed whose mean distances would differ but little from 3·27. These nascent planets, revolving in the same direction, and receiving gradual accretions of matter, would move with slightly different velocities. Collisions would therefore follow, until finally all would be collected into a single mass, whose period would be approximately half that of the disturbing planet. Such a result, though prevented in the asteroid zone by its extreme rarity, was realized in the case of Uranus. A similar formation would have taken place where the period of a planet would be nearly one-third that of Jupiter; corresponding to the ratio between the periods of Uranus and Saturn. Planetary aggregations might have occurred at intermediate distances, but in such case the close proximity of considerable masses would have resulted in collisions and "the survival of the fittest."

The inclinations of about three-fourths of the asteriods known are less than 10°, and but three have inclinations greater than 25°. When we consider the great number of these bodies, together with the fact that in their primitive, gaseous form their dimensions must have been much greater than at present, it seems not improbable that collisions may have occurred between comets and asteroids. The masses of the former are doubtless in some cases comparable to those of the latter. In the event of such impact, therefore, the direction of the planet's motion might be very much modified. Possibly the rare instances of great inclination may thus be explained.

The Solar Atmosphere, an Introduction to an Account of Researches made at the Allegheny Observatory. By S. P. Langley, of Allegheny, Penn.

It has long been observed that the sun is not everywhere equally bright, but that the edge is darker than the centre, and since a self-luminous sphere should appear of sensibly uniform brilliancy, so as to present to the eye the appearance of a flat disk, this diminution of light must be due to some medium external to the photosphere. Accordingly, even before the invention of the spectroscope, it was admitted that an absorbing atmosphere surrounded the sun, and that the effect would necessarily be to diminish the amount of the radiation. LaPlace, in the tenth book of the "Mecanïque Celeste," has attempted to compute the total effect of this absorption from data furnished by observations of Bouguer's, and considers that were the solar atmosphere removed, the light would be twelve times as great as at present. Though this value is erroneous, being deduced from imperfect data, by processes which rest on false hypotheses, it may yet serve to call attention to the importance of a somewhat neglected field of research, in which this observatory has been in part occupied during the past three years.

Several estimates of the absorptive power of this atmosphere have been made, differing widely from each other. According to that of LaPlace just cited, the absorption is about eleven-twelfths of the sun's emission; according to Liais less than one-twelfth, according to Secchi ·88. These discrepant results may be due in part to different hypotheses used in computation, but they are in every case founded on an experimental comparison of the light or heat of the sun observed at the centre, with that observed near the edge.

This direct comparison of the two lights, involves of course, no hypothesis, but is simply a photometric measurement, and apparently an easy one. Let us examine the result of this measurement at different hands. Arago,[1] using the Rochon prism, and analyser announced as the conclusion of a prolonged research, that the light observed at the centre of the solar disk, must be diminished by $\frac{1}{41}$ part or 2.4 per cent. to equal that of the edge. Liais, in a

[1] Oeuvres completes tom. 10e, page 235.

memoir[2] which is a model of conscientious care, announces from comparisons carried on through the extinction of one light by a stronger, that the central light should be diminished by about ten per cent. to equal that of the edge. His result then is four times Arago's. Secchi, with a wheel photometer, finds for a nearly corresponding point .78 per cent. as the amount by which the central light should be diminished. His result then is seven times that of Liais' and thirty times that of Arago's.

Secchi has made observations on the comparison of radiant heats, to be found in "Le Soleil,"[3] the most important results of which are, that the heat diminishes from the centre to the edge; that for a given point there is a satisfactory agreement between the absorption of light and heat; and that the equatorial regions are hotter than the polar. The present writer has made somewhat extended researches in the same direction, which are chiefly unpublished. Vogel has made interesting researches[4] on the relative actinic absorption.

None of those who have attempted to compute the amount of the solar absorption, appear to have drawn conclusions from their results as to its effects on terrestrial temperatures, and yet, if the absorption be anything like what has been found by LaPlace, and by Secchi using LaPlace's formulæ, the subject deserves attention.

It will be shown in a forthcoming memoir that the absorption is much less than these values, but that definite limits can be assigned in which it must lie, and that at any rate it is of such importance that the conditions of animal life upon this planet largely depend upon it. It will further appear probable that with a slight change in the depth and absorptive power of this atmosphere, fluctuations in terrestrial temperatures will ensue, very great in comparison to any actually observed within historic periods, and it will be shown that this atmosphere is not in a strictly stable condition. Though the subject then is a nearly neglected one, and the methods of investigation of less apparent interest than those of the spectroscopist, the results are, if verified, of a peculiar interest from their bearing upon the possible changes in the mean temperature and climatic conditions of our own planet.

[2] Memoirs de l'Academie de Cherbourgh.
[3] "Le Soleil" 2d Edition, Paris, 1875.
[4] Pogg. Annal., Jan., 1873.

The portion of this atmosphere chiefly concerned in absorption I have been led to believe from several considerations is extremely thin, and I am inclined to think this is nearly identical with the reversing layer at the base of the chromosphere, observed by Secchi and Young, though the chromospheric stratum may have some share in the obscuration observed.

The methods used at Allegheny for heat measurements have been partially described[5] and need not be enlarged upon here. Those for light are believed to be novel in their present application, and may be given briefly.

We have seen that a photometric comparison of the centre and edge of the sun, is for some reason attended with risk of error which we should not anticipate, but which must be great, from the enormous discrepancies of existing estimates among skilled observers; for taking Arago's value as the standard, Liais's is four hundred per cent. and Secchi's three thousand per cent. greater. Now skilled observers, in comparing their estimates of the excess of the light of a gas flame over that of a candle, for instance; by the familiar methods of ordinary photometry, need not be expected, as common experience shows, to commit errors which are in any way comparable to these.

If such familiar means as the Rumford and Bunsen Photometers could be used for the *direct* comparison of the two solar intensities, there seems no reason why the results should not be of the exactness obtainable in the physical laboratory, or at least of the same order of accuracy. If results can be obtained by such means, they may at least be hoped to be free from grave error.

At first sight it appears that these methods are not applicable to the direct comparison, for the ordinary use of either photometer supposes that the relative distances of the lights from the screen can be altered, while we cannot change the relative distances of the lights to be here compared, which are two portions of the sun, and if we attempt to enfeeble the stronger by shades, or by diffusing its light through a lens till it equals that of the other, seen direct, we lose the peculiar advantages of the methods which assume that the lights are viewed under the same conditions, and measured by the relative distances from the screen.

I arranged in June, 1874, an apparatus which appears to be free

[5] Comptes Rendus, May 22, 1875.

from these objections, and which is here described in principle, not in detail. Let us suppose that to the equatorial is attached a screen, upon which is described a large circle, whose radius is divided into one hundred equal parts, and whose centre is always in the prolongation of the optical axis. This screen receives an enlarged solar image from an amplifying lens. To fix our ideas, we may suppose that the circle and image are each always twenty-four inches in diameter, and that a direct comparison is to be made of the light at the centre with that of a point three-fourths of the way from the centre to the western edge of the sun. Two small[6] and equal circular apertures are made in the screen at points equidistant from the centre, or seventy-five divisions of the scale (three-fourths radius) apart. The telescope is directed to neither point under examination, but to a point of the solar disk three-eighths of the way from the centre to the western edge, and which is, therefore, mid-way between the points to be measured. The image of the centre now falls on one of the small apertures in the screen, that of the point under examination on the other, and through the apertures pass two cones of rays each slightly divergent; formed under precisely the same conditions, since they come from the same lens, and are equidistant from the optical axis. Two small prisms of total reflection (cut from the same piece of glass) are placed one behind each aperture, and these deflect the rays toward each other, so that the reflected portions of the cones, have a common axis behind and parallel to the screen, within a chamber which is lined with black, and shielded from light so as to form in fact a camera obscura. There is a small Bunsen disk behind the screen, and in the camera, whose centre remains in the axis common to the reflected cones, as it (the disk) slides back and forth on a graduated scale which measures its distance from the source of illumination. Evidently one light is diffused and the other concentrated by the disk's advance and recession upon the cones, sensibly as though these were formed by lights at their virtual apices beneath the screen, which were of the color and intensity of the portions of the sun under examination. In practice it is convenient to introduce a lens of short focus between each aperture and its reflector, so that the cones while still exactly similar, may be less acute. By the substitution for the Bunsen disk, of a small box, sliding also on the graduated scale and

[6] On this scale the diameter of each aperture is about ten seconds of arc.

containing a second screen, and a rod whose shadows are cast by means of a second pair of reflecting prisms, we convert the instrument into a Rumford Photometer, and in this form it has also been much used here. This application permits incidentally a comparison under very favorable circumstances of the *color* of the light from different parts of the sun, which is by no means uniform. When light from near the edge is juxtaposed with that from the centre, the shadow illuminated by the former is chocolate-red,[7] while that from the latter is by contrast of a peculiar bluish tint nearly like that given by the shade-glass, called by English opticians "London Smoke." (I use these comparisons, not being able, readily, to assimilate these colors to any of the pure spectrum). It is worth while to remark that this observation confirms others obtained from different means by the writer, who has elsewhere announced the fact of a selective absorption in the solar atmosphere, of such kind, that were this envelope removed, the gain in *light* would be greater than the gain in heat. The light we receive from the sun and universally call "white," is thus seen to be upon the whole less refrangible than that which the sun would emit if deprived of its atmosphere; in which case, it is hence evident that the color of our luminary as it grew brighter, would tend toward blue. If then, the depth of the atmosphere were sufficiently increased, our sun in growing darker would also appear more red. To more than suggest the possible influence of such a cause on the colored stars (among which the bluish are distinguished by the absence of absorptive spectra) and the desirability of ascertaining whether changes in color (if any such are verifiable), are or are not, accompanied by slight changes in apparent magnitude, would lead us away from the immediate subject.

So clear an exhibition of color in the actual comparison is a sign of the delicacy of the Rumford method, but it introduces a disturbance in our estimation of the intensities of colored lights. An arrangement of the Masson Photometer in which black and white sectors, on a rapidly revolving disk illuminated by the colored light are viewed by the intermittent electric discharge, has been prepared to obviate this, but the complete examination is intended to include that of juxtaposed spectra formed from the lights under examination, selected portions of which of different

[7] This color appears to have passed unnoticed by all observers but Secchi, who remarks that the edge of the disk is smoky-red.

wave lengths, will be compared as regards intensity, by processes which are a development of those mentioned above. In all such comparisons the apparatus is reversible, so as to eliminate any inequalities in the material, position, or condition of the rays, under examination, due to the instrument; and in practice, corrections for every form of instrumental error are applied, which are not here mentioned.

The methods above indicated are, with some slight modification, evidently adapted to the comparison of the light of sun spots and the light adjacent to the limb, with that of the centre; to studying the rate of diminution of light without the disk, and to like investigations; and they are now being so used.

Without entering into detail I may observe that the measurements of the light of spots, though as yet incomplete, warrant me in stating that the absorption of the more refrangible rays, though great in reference to that of the less refrangible, is not so great as would appear from published measurements. It has long been supposed that the umbræ of spots were not absolutely dark, while it has been admitted from Dawes' observation, that there is within the umbra a sensibly black "nucleus," and from the assumed blackness of this nucleus several astronomers have been led to infer that the nuclei are not openings into a dark gaseous interior.

The measurement of umbræ, and of so-called "nuclei," here shows not only that neither are absolutely dark, but that the absolute light of either is enormous, that of the average nucleus, so-called, being as I find, at least five thousand times that of the full moon.

LaPlace, assuming that the radiation in any direction is constant, and is proportional to the radiating area (or that the radiation is infinite at the edge of the disk), concludes that the emission is represented by the expression

$$2\pi \int^{\prime} \epsilon^{-\frac{f}{\cos\theta}} \sin\theta \, d\theta$$

where θ is the heliocentric angle between the earth and the point of the solar surface under examination, and this assumption has been adopted by Father Secchi, who in his latest edition of "Le Soleil," gives results derived from the use of this integral. I shall assume in accordance with what seem to be the teachings of modern physics, that a globe as large as the sun, whose photosphere though perhaps composed of very light vaporous material, is yet

opake at a limited depth (as observations on superposition of solar cloud-strata have shown), that in such a globe, radiation would be proportional to the cosine of the angle under which the surface is seen, or that the sun deprived of its atmosphere would appear as a flat disk, whence it will follow that the total radiation of the sun without an atmosphere being unity, that which escapes through the atmosphere, will be, if we adopt La Place's formulæ with this correction

$$2\pi \int_0^1 e^{-\frac{f}{\cos\theta}} \cos\theta \sin\theta \, d\theta$$

These expressions should give from any observation of the heat at a given point of the disk, to that of the centre, a certain value of the absorption which should be constant for any value of θ. In fact, I find however, that this is not the case. The discrepancies in the summation I obtain for different values of θ are not casual and irregular as they would be if due to errors of observation, but are systematic. This formula even as corrected, in fact rests on assumptions, which are far from the truth as it seems to me. These defective assumptions as they appear to be, I expect to point out in a definite form, in a subsequent memoir. It seems better then, to defer a statement of the amount by which the solar radiation is absorbed by its atmosphere until it is accompanied by demonstration. I will only here repeat that we may feel certain that the estimates cited from LaPlace and Secchi, and which make the sun's atmosphere absorb from seven-eighths to eleven-twelfths of the radiation we should receive in its absence, are far in excess of the truth. For the purpose of a first approximation I may also state that from my computations, of the so-called luminous heat rays, somewhat less than one-half the whole are absorbed, suffer reflection, or conversion into work in the sun's atmosphere. The total thermal absorption is again somewhat less than that of the luminous heat, if, however, we admit this result provisionally, then certain results seem to follow which deserve mention.

The mean surface temperature of our globe is separated from that of absolute zero by a little over 500° of the Fahrenheit scale. The internal heat supplied to the surface is here negligable. The temperature of interplanetary space is according to Fourier — 60 C., according to Pouillet — 142, according to Liais — 97. Liais, in a memoir whence we cite these estimates, admits as a consequence

of his own, that the obscure heat received at the upper limit of our atmosphere from space (i. e., from the chiefly non-luminous matter which occupies it) is greater than that furnished directly by the sun, a conclusion which we are not called upon here to adopt, further than to observe that on this, as on either of the other estimates, the obscure heat received from interplanetary matter by reflection from the sun at the surface of our atmosphere, is considerable, so that if our luminary were wholly extinguished, the temperature of the earth would fall much below that it would reach if only the direct solar heat were withdrawn.

We should, perhaps, be warranted in entertaining it then as a reasonable assumption, that in the complete absence of the sun the earth's temperature would fall very nearly to—273 C. We prefer as the basis of an estimate, confessedly but approximate, to take the mean of this value and of Pouillet's, and using the Fahrenheit scale, we may then state that of the 500° F. which on the natural scale is the approximate mean temperature of our globe, as much as four-fifths is derived from the sun.

If it be true then that the sun is surrounded by an atmosphere whose principal action in obscuring the heat radiation is due to a thin stratum which cuts off one-half of the heat which should reach us, and in whose absence this radiation should be doubled; an atmosphere not independent of the interior of its globe in such degree as our own, but one to and from which matter is constantly being added and withdrawn, it follows that any change in the ratio of supply and withdrawal, or other cause which should increase its absorption, by so much as 25 per cent. would diminish the mean surface temperature of our globe by 100 F., whilst a like diminution would produce a corresponding change in the opposite direction.

I am unable to see that if these observations are correct, any other result would follow, and in either case the existence of life in its present forms on this planet seems dependent on the constancy within certain limits, of the depth and absorptive power of this solar envelope. The reader who may not have closely observed how far the validity of this result is dependent on, and how far independent of the hypothesis just made as to the mean terrestrial temperature, is invited to remark that there is nothing, in any case, hypothetical in the assertion that the earth would fall in the absence of the sun to a mean temperature as low as any actually observed

on its surface. If any value attach to the writer's measurements then, it will be found from a repetition of the calculations with (arctic) terrestrial temperatures *actually observed*, and hence within the truth, that the result remains, that a comparatively slight thickening of the solar atmosphere, or a comparatively slight increment of its absorptive power, would bring this planet back to what we must suppose were the temperatures of the glacial epochs.

Father Secchi seems to think it probable, that the difference between the results of the measurements of the heat at different portions of the solar disk made at Rome in 1852, and at Allegheny in 1873–4, are explicable by a real change in the atmosphere of our luminary. To the writer it seems that such a change as Father Secchi assumes, if real, is (if interpreted by Father Secchi's own formulæ) likely to have already altered the mean annual temperature of our globe to an amount sensible to every inhabitant of its surface. He is himself therefore of the opinion expressed by M. Faye, that no evidence of real variation has yet been established.

It will not of course follow that changes may not take place in cycles of time long with reference to historical periods. All analogy leads us indeed to think an absolute uniformity here most improbable.

Finally then, it appears that though we are justified on grounds established by Helmboltz and Ericsson, in believing in the constancy of the heat supply *within* the solar envelope for periods to come, which are with reference to our terrestrial part, almost infinite, we are not justified by our present investigations, in asserting that the solar radiation has been constant during geologic periods, or is certain or even likely to remain what we now see it during corresponding periods in the future.

If there be great cyclical changes of long period (and in our present ignorance we can only say that such are not antecedently improbable), there will be corresponding cyclical changes in terrestrial temperature, and it is allowable to inquire whether we do not find here matter for consideration, in connection with those great changes of temperature on the earth in past epochs, which have in them nothing hypothetical, which geology assures us to have indeed existed, and for whose possible cause no satisfactory suggestion has hitherto been made.

THE SUBSIDIARY PRINCIPLE APPLIED TO COINAGE AND MONEY OF ACCOUNT. By E. B. ELLIOTT, of Washington, D. C.

IN the markets of the world, the values of commodities are constantly fluctuating. Gold and silver are not exceptions to this rule, and they, like other commodities, change in relative value. These metals have been selected from time immemorial, as the best for the purposes of money. Their cost of production varies but little from decade to decade. While the fluctuation in their relative value is constantly taking place it is comparatively smaller with these metals than obtains in general with other commodities. It is, however, appreciable, and a constancy of relative value between the two methods, however desirable it may seem, is not attainable.

Great Britain was the first to devise, and in 1816 to apply, the principle by which this obstacle to the simultaneous and harmonious circulation of the two metals as money could be surmounted, namely: the rendering of one of the two fluctuating commodities subsidiary to the other. The method was, in short, the making gold a legal tender for all amounts, and silver a legal tender only for sums not exceeding forty shillings in one payment. Prior to this time a double standard had been customary in England, gold and silver being each legal tender for all amounts, with results such as are uniformly experienced in countries where the double standard legally exists, the market ratio of value constantly varying, sometimes rising above and sometimes falling below the mint standard, each metal in turn, as it became the cheaper, driving the other from circulation. A frequent result was a call for new legislation on the subject, which usually tended to reduce the value of the monetary unit by diminishing the proportionate quantity of metal in that element of the double standard which for the time being had a market value relatively greater than that assigned to it by law.

In the year 1853, the United States adopted the subsidiary principle in respect to the fractional silver coins, and such silver was made a legal tender in sums of five dollars and under. But the subsidiary relation was confined to fractional coin (or coin of less nominal value than one dollar) and did not apply to the silver dollar until the year 1873, when the coinage of the hitherto legal tender silver dollar was discontinued, and that of a subsidiary

"trade dollar" so-called, legal tender in sums not exceeding five dollars, was authorized in its place.

In the United States no inconvenience ensued, owing to the fact that the ratio of the value of gold to that of silver adopted by the mint, was during that period always in excess of the fluctuating market ratio, the former being sixteen to one, while the latter was between fifteen and one-fourth and fifteen and six-tenths to one. The legal tender silver was thus undervalued and consequently was practically demonetized, since no one would make payments in the relatively dearer silver dollar when the cheaper gold would avail.

France, jointly with Switzerland, Italy and Belgium, adopted, in part, the subsidiary principle at their Quadripartite Convention held in 1835, silver coins of lower denomination than five francs being reduced in fineness, the weight remaining unchanged, and limited as legal tender to sums not exceeding fifty francs. But the silver five-franc piece, like the United States silver dollar, was still permitted to remain a legal tender for all amounts. Unlike the United States, however, these countries did suffer inconvenience from the change, the mint ratio assumed being fifteen and one-half to one, while the market ratio fluctuated above and below that point. From the year 1852 to about the year 1870, the fluctuating market ratio averaged fifteen and three-eighths to one, and gold circulated to the exclusion of the legal tender silver. Since then the market ratio has risen to a point above the mint standard, and given a tendency to silver to circulate to the exclusion of gold, which latter has now become relatively the dearer. This tendency, the Governments represented in the Quadripartite Convention, have partly counteracted by retiring the legal tender silver, and diminishing the amount of its coinage.

Germany and the Scandinavian countries of Sweden, Norway and Denmark, have lately endeavored to recede from their former exclusive silver standard and to adopt instead a gold standard, legal tender in all amounts, with a new subsidiary silver coinage restricted as legal tender to limited amounts. But Germany, like France with respect to its silver five-franc piece, retained and still retains a part of its old silver coinage, the thaler-piece, a legal tender in all amounts. As a result, she has experienced great difficulty in placing her newly coined issue of gold in the market, such gold either being at once exported, which is commonly the

case, or, being remelted at home. In establishing the new coinage the German Government assumed the ratio of the value of gold to that of silver at fifteen and one-half to one, by fixing the relative weights of the two metals for like denominations upon that basis. The market value in the same period was sixteen and one-half to one, and the silver being relatively the cheaper, excluded the gold from circulation.

Germany suffers from embarrassment on this account, not even legislative enactments or an Emperor's edicts enabling the two metals to circulate simultaneously when that would conflict with the laws of trade. To demonetise her former silver standard at once might have the effect of injuring public confidence by impair ing the faith of contracts.

A slower process, and perhaps a safer, would be to declare the old standard silver coinage a legal tender only in limited amounts, instead of, as now, in all amounts; not necessarily, however, in limits so narrow as those which have been adopted by other and by the Germans themselves for their new coinage. The range should not be so great as to include all the larger transactions of the market as shown at the clearing-house. It seems not unlikely that a favorable result would follow the declaring of this form of silver coinage a legal tender, at first in sums not exceeding $1,000, this limit to be thereafter reduced as expediency may dictate until the value of such silver should rise nearly to the new gold standard.

The relations of gold to greenbacks in this country, and of gold to silver in Germany, are, to a certain extent, similar, and it is worthy of consideration whether the United States might not find its efforts to bring about the redemption of our paper currency in 1879, authorized by the late act of Congress, facilitated by adopting as one of the methods of attaining this object, the declaration that the greenback currency should be a legal tender only within some certain large but limited amount. The limit might be gradually reduced to a smaller amount after an opportunity had been afforded to observe the first effects of the new movement.

ACCOUNT OF A BASELINE MEASUREMENT, THREE TIMES REPEATED, IN THE U. S. COAST SURVEY.[1] By J. E. HILGARD, of Washington, D. C.

THE measurement of a baseline is the most important and delicate operation of a geodesic Survey, and in all works of the kind the greatest pains have been taken to obtain this fundamental element of length with the utmost attainable accuracy. The apparatus for measuring baselines used in the U. S. Coast Survey, has been described to this Association at its meeting in 1854 (see volume of Washington meeting) by the late E. B. Hunt, Major of Engineers, at that time attached to the Coast Survey service. For the mechanical details of the apparatus, the illustrative plates appended to the present paper may be referred to. It will be sufficient here to recapitulate its principal features, and to mention an important addition recently made.

The principal objects to be had in view in the measurement are, first, the accurate repetition of the unit of length which is employed, and, second, the ascertainment of its length during measure, or, in other words, the keeping account of the changes of length occasioned by temperature. Among the most obvious means of testing the correctness of the allowance made in that respect, is that of measuring the same line at greatly differing temperatures, and thus ascertaining the correction for temperature by actual application of the unit to the whole length to be measured. That, however, is a very expensive operation, and has not been often undertaken.

Within two years, however, a baseline of about six miles in length, situated near Atlanta, Georgia, has been measured in the Coast Survey, in connection with the extension of the primary triangulation along the Appalachian Chain, and in order to test its accuracy the operation was performed three times. After the first measure, which was made at a rather low temperature late in the autumn, it was again measured at nearly the same temperature, but in the inverse direction, in order to test the accuracy with which the measurement could be repeated under the same conditions, but inverting the operation of a certain class of errors, viz.: those arising from the instability of the apparatus or inclined

[1] Communicated, with the permission of the Superintendent, by J. E. Hilgard, Assistant U. S. Coast Survey.

grades. A third measurement was undertaken the next following summer, at a temperature 46° higher than the temperature at which the winter measurement had been made.

The results of these three measurements agree in a most extraordinary manner, the greatest divergence being less than the millionth part of the whole length. We may recall, in order to get a comparison for this degree of accuracy, that until very lately, until in fact the construction of the apparatus for the International Standards Commission, it has been thought a good result to compare single metre-bars with each other, to the accuracy of a thousandth part of a millimetre. It will be observed that this is a millionth part of the whole—precisely the accuracy which we have attained in the measurement of six miles.

I have at once put forth the result as the warrant for the more detailed statement which I am about to make, of the quantities involved in the experiment, and, without entering into unnecessary detail, will now recite the conditions upon which the use of the apparatus of the Coast Survey rests.

It is, in the first instance, a compensating apparatus, so contrived, by the combination of a bar of iron and a bar of brass, of six metres or about twenty feet in length, as to maintain nearly the same length at all temperatures. This is effected, not only with regard to stationary temperatures, by means of an appropriate lever arrangement, such as occurs in compensating pendulums, and may be made in different modes; but it is also so formed as to maintain the compensation during changes of temperature; that is to say, the two bars are so proportioned in mass and thickness to their relative specific heat and conductivity, that they will change temperature equally in equal times—an element which had not been considered in the compensating-bars, that had been constructed previously, either those of Mr. Borden of Massachusetts, or of Col. Colby, of the British Survey.

This compensation, of course, cannot be supposed to be effected with absolute precision, as in every mechanical arrangement some residual error remains, and consequently some correction must be applied. The great gain consists in this, that when we have reduced the correction arising from the change of length by temperature to about its fiftieth part (which has been effected), then we need not concern ourselves so much as to the precise temperature of the bars at the time of measurement. And nothing is more

difficult than to ascertain the temperature of any one piece of substance by some other piece or apparatus, such as the thermometer. The thermometer will show its own temperature, but to make it show the temperature of something else, is quite another matter, and especially difficult in the field-measurements, where the bars are exposed to the influence of the sun; and although protected by a proper casing, are still subject to very great variations of temperature.

Furthermore, the compensation itself is necessarily effected by mechanical means. There are moving parts; there are knife-edges which will wear; and no such thing as permanence can be expected in a compound apparatus of that sort, which is, therefore, used only as a means of repeating a certain unit of length, to which it is frequently referred by comparisons with a permanent standard, consisting of a single bar of metal which is not subject to any other changes except those of temperature.

The operation of a base-measurement consists, so far as the value of the unit of length is concerned, in this; before the measurement is actually undertaken on the ground, after the apparatus has undergone transportation by railway, the measuring bars are compared with an iron standard bar of six metres that has been carried along, and which is at least, not subject to any mechanical changes. To obviate doubt as to any molecular changes in this bar, affecting its length, it is compared, before being taken to the field and after its return, with a similar bar kept constantly at the office in Washington. After the measurement the apparatus is again compared with this standard, so that the apparatus serves merely to carry forward the length of the standard without change from temperature, and the baseline is actually measured in the terms of the standard bar, to which the measuring bars are constantly referred. The mean temperature of these comparisons will generally differ but a few degrees from that of the base-measurement itself, and it is only for such difference that any error in the compensation can affect the result. The whole reduction for temperature, therefore, is thrown upon the standard bar, that is, the reduction of its length at the actual temperature of comparison with the measuring-bars to that temperature at which it has the exact length of six metres. It is, therefore, of the greatest importance to know accurately the length of that bar at different temperatures, or, in other words, its rate of expansion.

I omit, in this statement, any description of the manner in which a bar of six metres was obtained from a single metre (referring only to the Coast Survey Report for 1862, Appendix No. 46), for I consider the baseline expressed in terms of this six-metre bar, as it was then, it being the actual unit employed. Of course, its uncertainty is far less as expressed by that unit, than in terms of one metre to which that length of six metres must be referred.

Now, in order to obtain the length of the six-metre bar at different temperatures, or its rate of expansion, there were made, under my immediate direction, about fifteen years ago, experiments, which were conducted, by permission of Prof. Henry, in the vaults of the Smithsonian Institution. They have been published in the Coast Survey Report for 1862, but this is perhaps, the first occasion that has presented itself, of demonstrating their great accuracy and of drawing more particular attention to them.

During these experiments, the bar, accompanied by five thermometers, was immersed in a box filled with sperm oil, of which fifty gallons were employed. Water would have been preferable, on account of its great specific heat, but the bar being of iron it was not admissible. The thermometers and bar being thus inserted in a very considerable mass of oil, there was reason to suppose they would indicate the actual temperature of the bar. To change the temperature, a system of iron pipes was so arranged in the corners of the box, as to admit of the circulation of hot or cold water, moved by means of a small hand-pump. In heating from about 39°—which was really the lowest temperature that we could permanently maintain in the mean temperature of the vault, which was 45°—up to about 96°, ten hours were occupied, but notwithstanding this slow increase the thermometers got sensibly ahead of the bar; so that the series, as protracted upon rising temperatures, were useless for discussion. It was only when some high point had been reached and maintained for some time and then the natural cooling allowed to take place, which spread over a period of forty-eight hours, that the results represented in the diagram were obtained. The annexed plate gives, besides a section of the box, showing the bar supported upon rollers and the arrangement of the heating pipes, a graphic representation of the four series of observations, marked A, B, C, D, in which the actual expansion is magnified one hundred and twenty times. The

temperature scale for each series is moved down 5° below the preceding one, in order to separate the lines joining the points of observations. The straightness of these lines corresponds, of course, to a uniform rate of expansion, their parallel course to the same rate in the different series. Their length varies with the different range of temperature through which that series was carried. The longest line here represents an expansion of nearly one-tenth of an inch, which was experienced between temperatures of about 34° to 94°. A single glance at the diagram suffices to show a great accordance in the observations. The results of the several series, when expressed in the form of the coefficient of expansion, are as follows:

A.	Coefficient of expansion for 1° Fahr.=	0.000,006,430
B.	Coefficient of expansion for 1° Fahr.=	6,405
C.	Coefficient of expansion for 1° Fahr.=	6,407
D.	Coefficient of expansion for 1° Fahr.=	6,400
Mean.	Coefficient of expansion for 1° Fahr.=	0.000,006,410

with a probable error, from all sources, of perhaps $\pm$ 0.000,000,02. As the six-meter bar has its standard length near the temperature of melting ice, the uncertainty of the length assignable to it at other temperatures increases with the difference of temperature from 32°; thus at 82° its length will be increased by $50 \times 6 \times 0.000{,}000{,}641 = 0.001{,}923$ metres or nearly two millimetres, and the uncertainty of this increase will be 0.000,006 metres, which is the millionth part of the whole length.

In the correction for temperature resides the main difficulty in the measurement of a base-line. The method of repetition, that is to say, of contact, whether optical or actual, is readily made so accurate that the accumulating error from that source is wholly insignificant in the length. For there will be naturally a compensation of this class of errors, and if we admit them to be as likely to occur in one direction as in the other, then in sixteen hundred contacts the probable error of one contact will be augmented only forty times. Now, that there should be an error so great as the thousandth part of an inch, can be admitted only with the rudest sort of linear optical contact looked on with the magnifier, for an ordinary vernier reading on a divided circle of eight inches diameter has an accuracy of about the ten-thousandth of an inch.

But in the use of this apparatus there is another source of error dependent on a quality possessed by it, which determines the great facility for its use in the field, namely, the arrangement by which it is possible to use it at different inclinations. By reference to fig. 3, the mode in which the contact-rod acts upon the tilting level is clearly seen: it is pushed back against a curved abutting piece which tilts the level on its pivots until its bubble stands in the middle—in which position the "tube" or measuring-bar has been compared with the standard. Now, when the bar is placed at an inclination to the horizon, the sector which carries the tilting-level and curved abutting piece is turned about its centre into a horizontal position, indicated by the large spirit-level attached to it. The end of the contact-rod will now abut against some other part of the curve, but if the latter is a true circle the centre of which coincides with the centre of motion of the sector, the length of the measuring-bar will remain unchanged. It is only necessary then to reduce the length to the horizon by the angle of inclination, which can be very accurately read on the divided arc.

The adjustment of the curved abutting-piece to the required position has of course been made the subject of most careful experiment in the workshop. It will be readily seen that if it is not correctly adjusted, the effect of the error will be in opposite directions for upward or downward inclinations, and will therefore be inverted when the direction of measurement is inverted.

The same change in the direction of effect upon the measured length obtains for any sliding of the bars on their supports. In this particular base-line several series of tubes were measured with inclinations of about four degrees, especially near the ends of the line, which were necessarily chosen on elevated ground. In such cases the reduction for the versed sine becomes quite considerable, and the angle of inclination requires to be measured with great accuracy. The aggregate correction for inclination amounted to nearly twelve metres, or about thirty-nine feet.

The measurements in opposite directions at nearly the same average temperature, thus served as a test of the perfection of the apparatus in respect to the two conditions just specified, while that made at a very high temperature verified the compensation of the measuring-bars, and the rate of expansion adopted for the standard bar. The difference in the reduction for temperatures

between the summer and winter measures amounts to 2.76 metr
or a little over nine feet.

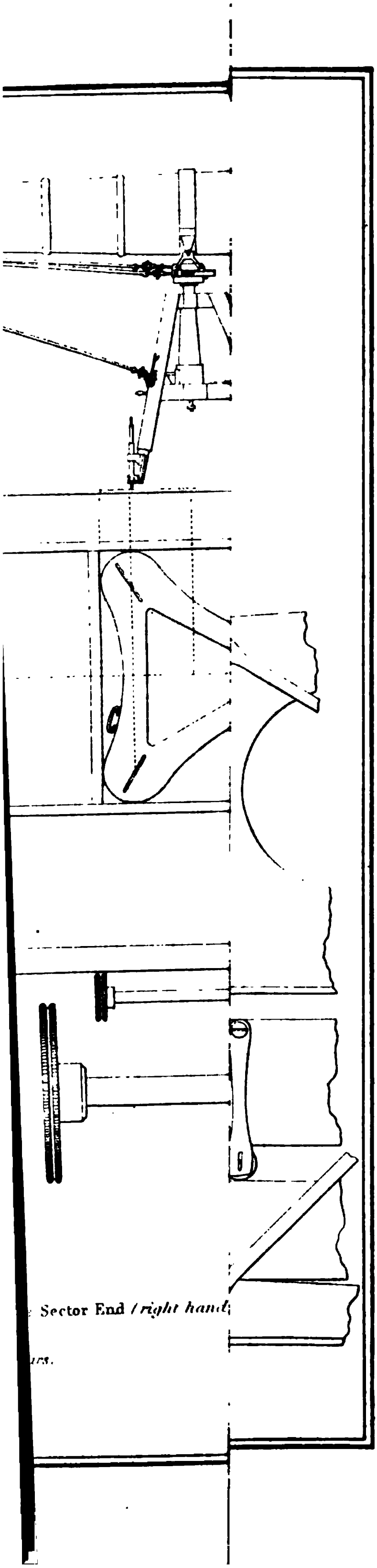
Not only was the Atlanta base-line measured three times, as d
scribed, but at each mile a permanent mark was made, and
three measurements compared; so that we have eighteen comp
isons, and are able to deduce the probable error of our operati
with far greater confidence than we could derive from merely t
coincidence of three separate measures of the entire distance.

The following table gives in millimetres the differences at t
several monuments of each measure from their common mean.

LINE.	DISTANCE.	TEMP. 52°. First measure.	TEMP. 44°. Second measure.	TEMP. 90°. Third measure
		mm	mm	mm
S. W. to I.	1636m	−5·09	+1·76	+3·32
I to II.	1642	+0·90	−2·88	+1·97
II to M.	1234	+4·87	−0·23	−4·14
M to IV.	1349	−2·29	+3·38	−1·08
IV to V.	1786	−2·68	+1·50	+1·18
V to N. E.	1692	−3·31	−3·85	+7·16
S. W. to N. E.	9339	−8·10	−0·32	+8·41

This table shows a maximum deviation of less than one in
million; the frequent change of sign indicates that no consider-
able constant error exists in any one of the three measures, and
that the residuals are not in any considerable degree affected by
the correction for temperature. They are mainly due to the
mechanical uncertainty of the measurement, among which is the
stabilility of the apparatus, or the perfection with which each
tube retains its place during the time between its being put in
contact with the preceding bar, and the completion of the next
contact against its forward end. I take it that here we have the
chief source of the variations in the whole affair. The stability
of the apparatus is, however, very great.

It will be of interest to know that after the line has been graded
the measurement can readily be made at the rate of one bar in
three minutes, and ten working days of eight hours will suffice to

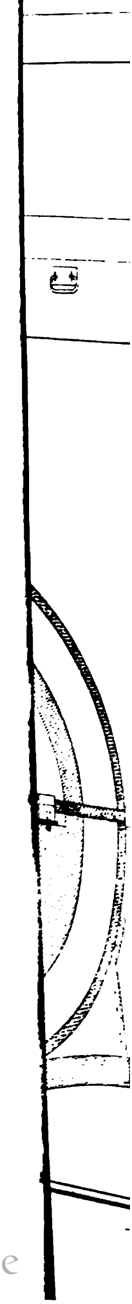


Sector End (right hand

...urs.

Fig. 11

Scale =



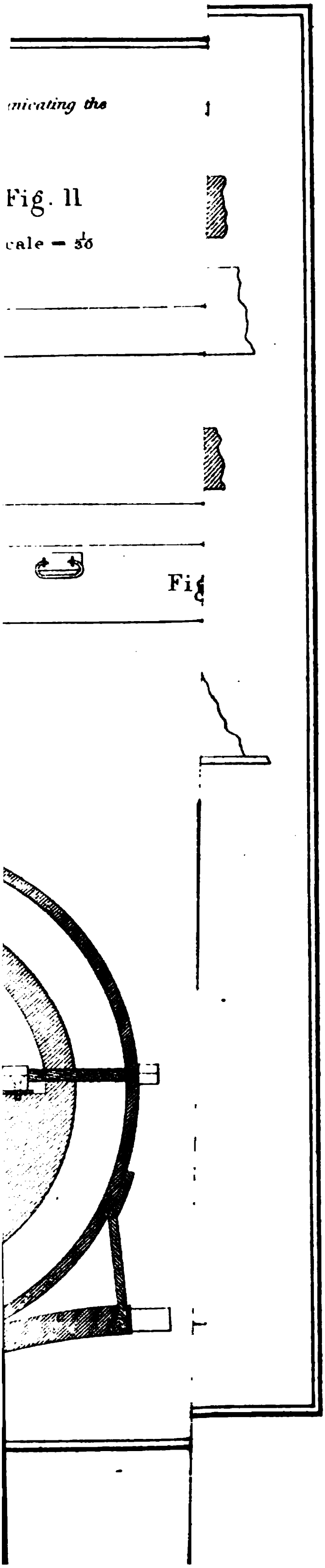

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Fig. 11
cale = 1/30
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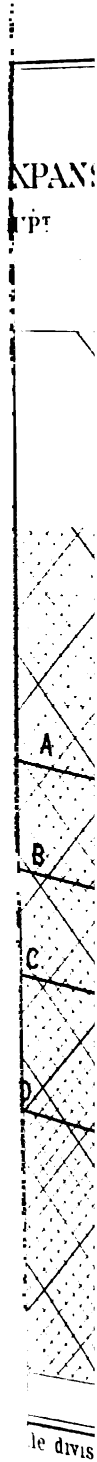
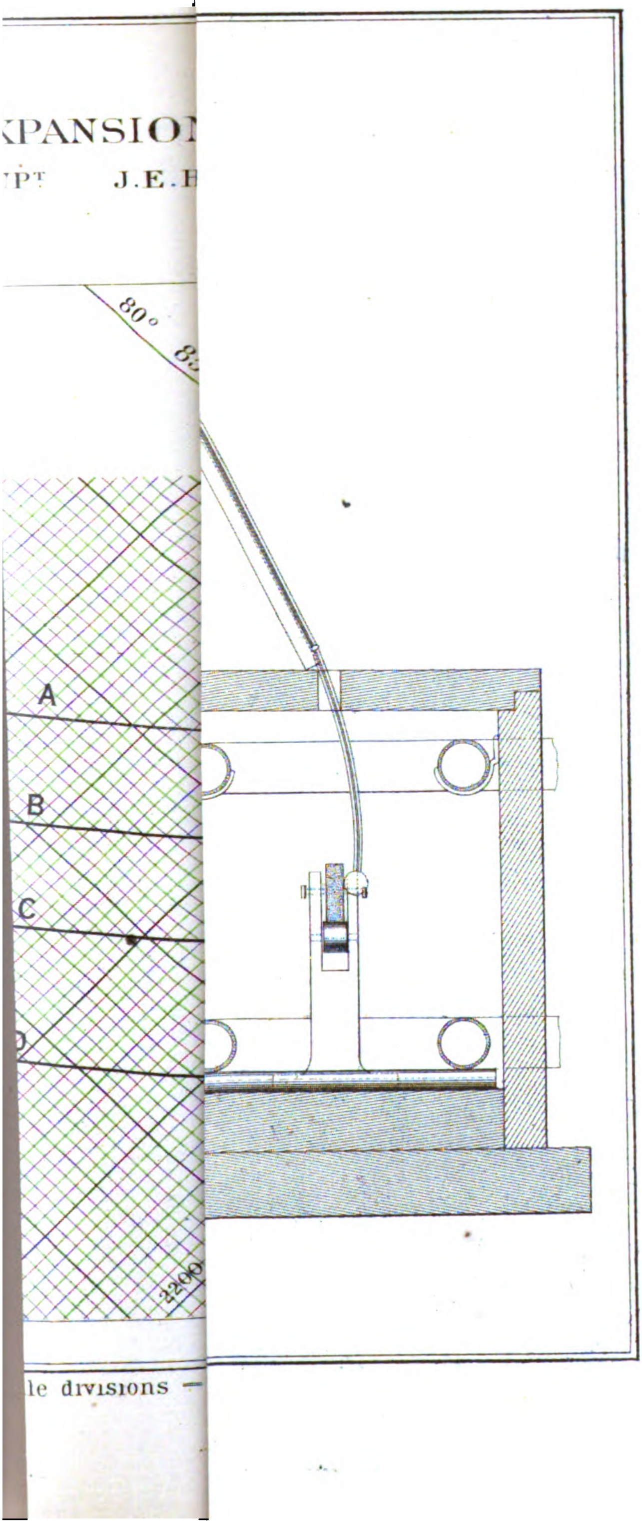

A
B
C
D



measure a base-line of six miles. The comparisons with the standard consume about four days in addition.

Some personal facts remain to be mentioned. The Atlanta base-line was measured in the winter of 1872, and in the following summer, under the direction of Professor Benjamin Peirce, Superintendent, by C. O. Boutelle, Assistant in the Coast Survey, to whose skill and perseverance the success of the operation is mainly due. He proposed the second measurement in the opposite direction to the first, and when subsequently instructed to repeat it once more at a high temperature, adopted the plan of immersing the standard, during comparison, in a liquid — for which he chose glycerine — in order to obtain its temperature more nearly by means of thermometers likewise immersed, than can be done when both are in air. This had not been done previously for the comparisons made in the field.

Up to 1874, the indications of the thermometers within the tubes have been taken as the means for applying any residual correction for want of perfect compensation which might be shown to be requisite. While this correction is only of very small amount, and affects the length of a base only so far as the mean temperature during the measurement of a base-line is different from that at which the apparatus has been compared with the standard bar, it is, nevertheless, subject to the uncertainty arising from the fact that those thermometers do not show the actual temperature of the compensating-bars, except when the temperature has been stationary for some time. In order to obviate this source of error, an arrangement has been designed and adapted to the apparatus by the author of this paper, by which the difference in the length of the two bars may be read on a scale attached to the iron bar by means of a vernier fixed to the brass bar, forming a "Borda thermometer," as shown in Fig. 3. The scale is divided to half-millimetres, of which the vernier indicates the fiftieth part, so that, by means of a long-focus microscope, the difference may be read to the hundredth part of a millimeter without opening the case. Since the compensation can readily be made correct to within its thirtieth part, it is evident that the true length of the compound bars may be inferred at any time from the indications of the scale-reading, with an uncertainty no greater than the thousandth part of a millimeter, or a *micron*, as that value is now called. In making this correction, no reference to the thermometers is necessary, as

the length is directly derived from the scale-readings. In the comparisons of the compensating measuring bars with the six-metre standard, the latter is immersed in glycerine, and its temperature and inferred length are very closely indicated by the thermometers distributed along its entire length, nearly in contact with it, and of course equally immersed in the liquid.

SUBSECTION OF CHEMISTRY.

CHEMISTRY OF THREE DIMENSIONS. By FRANK WIGGLESWORTH CLARKE, of Cincinnati, Ohio.

PROBABLY no questions in chemistry are to-day of more general interest than those which relate to the internal structure of compound molecules. In some directions the problems involved are being vigorously attacked, especially by organic chemists of the modern school. Every attempt at a rational formula, every research into isomerism, represents a new foothold gained by science, and a new point from which to start further investigations. But only a few chemists have yet tried to grapple the central problem of all—that of the actual arrangement of the atoms in space. Some efforts have been made to deal with this question from its crystallographic side, efforts which were both earnest and able, but somewhat premature; at all events they have not yet led us to altogether satisfactory results. The chief difficulties in the way of such researches lie in our ignorance of the actual nature of the so-called chemical elements; whether they are really elementary or not; whether what we look upon as atoms may not be in fact complex molecules. Preliminary to the complete solution of this great problem we need thorough investigations into the physical properties of every supposed element, not excepting the rarest; and much more elaborate studies of the optical, thermal, and crystallographic relations of compound bodies than have yet been made.

These few prefatory remarks may, perhaps, suggest what I mean by the somewhat novel title of "chemistry of three dimensions." The moment we conceive of a molecule built up of many atoms, we can hardly avoid considering these atoms as so arranged in space as to form a body having three dimensions. With a molecule consisting of few atoms the case may be different. Let us for present purposes suppose that our so-called elements are truly elementary, and that the atoms with which modern chemical formulæ deal are actual atoms, and not the molecules of unanalyzed compound radicals. It is then evident that any molecule

which contains but two atoms, for example, the molecule of hydrochloric acid, can have but one dimension involved in its structure, since both atoms must be in one line. Of course I do not mean to assert that these atoms are mere mathematical points, so that the molecule formed by them could have neither breadth nor thickness, but simply that their centres must lie in a single line through which alone the intermolecular or attractive forces can play. If we have three atoms to deal with, they may be placed either in one line, or in a form having two dimensions, but at all events must lie within a single plane. But as soon as we reach four atoms, although these may be all in one line or in one plane, it is clear that a solid arrangement can exist, and that a relatively complicated interaction of atomic forces has to be considered. Molecules then, according to modern chemical ideas, may be either of one, two, or three dimensions in the placing of their atoms, every additional atom increasing the complexity of the mutual attractions which bind the whole cluster together. But if it should ever be proved that only molecules of three dimensions can actually exist, it would follow that each one must contain at least four atoms, and consequently that many familiar substances are much more complex in structure than we at present imagine. This line of speculation, however, fascinating as it may seem, is rather more fertile in fancies than in tangible results.

I have already expressed the opinion that attempts to determine the actual arrangement of the atoms in space are premature; since, as it appears to me, we have too little firm experimental ground to go upon. And yet we may consider the problem a little, in a provisional way, in order to see what bearings some of our generally received chemical theories have upon it. My present purpose is to examine the question in its connection with the prevalent views regarding atomicity or quantivalence. For the time being I will restrict my considerations to that form of the theory of quantivalence which regards the valency of each element as invariable, and ascribes seeming variations to molecular as distinct from atomic union. I may state in advance, however, that I do not myself accept this view of quantivalence; my purpose is to see what bearing it has upon the main question. If I am led to conceptions which seem at all awkward, or grotesque, the theory is to blame for them. I am well aware that the advocates of fixed quantivalence generally disclaim all intention

to represent the position of the atoms in space; still, if their main hypothesis be accepted, certain conclusions of this sort are inevitable. These conclusions have been repeatedly put forward in modern text-books, and I merely bring them up again with their disclaimed and disowned features foremost.

When we conceive of the union of strictly univalent atoms with one another, we see that they must unite in a single, definite manner. The atom of one saturates an atom of the other, and a linear molecule results. In other words, a compound containing only univalent elements can have but two atoms in its molecule, and that molecule is inevitably of one dimension.

If we consider the case of molecules formed by bivalent atoms only, we shall find that they must be either linear or of two dimensions; at all events they lie in a single plane. A number of atoms, each of which has only two points of connection with its neighbors, cannot be arranged in any other way. They may be in line with the end affinities free, or in a ring with all the bonds satisfied; but a solid structure is impossible. Taking univalent and bivalent atoms together we shall find ourselves still more limited, since the molecule containing both can be only linear. It must consist of a bivalent atom, or a bivalent chain with a univalent atom at each end. A univalent atom could not exist in the middle of the chain, for then it would be connected with two other atoms, which is contrary to the hypothesis. Let us, for example, imagine the molecule of sulphuric acid H_2SO_4. In this, if the form of the theory of quantivalence now under consideration be true, the hydrogen must be univalent, and the sulphur and oxygen each have a valency of two. Here then we have a molecule of seven atoms, all strung like beads along one line of attraction. As far as we know, this line may be either straight, or curved, or bent at right angles, or doubled back upon itself; but the atoms can only form a simple chain without any other interlinking. Try to conceive of a gaseous mixture containing, among a number of molecules of three dimensions, a few molecules of this kind — not of sulphuric acid necessarily, but of some substance built upon this general plan; and imagine what kind of motion such an atomic chain would have. Of course we cannot say what would really happen, but it seems as if with this unfortunate molecule its number of encounters would be alarmingly disproportionate to the length of its free path, if, indeed, it could

have any free path at all. We might almost suppose it to suffer as much perturbation as did the comet's tail among the moons of Jupiter.

It is not until we begin to deal with trivalent atoms that molecules of three dimensions become possible. For no such structure can exist unless some of its atoms are in union each with at least three others. If a molecule consists of four atoms only, it can form no solid structure except the tetrahedron; and in this every atom must have a valency of not less than three. In fact, no molecule of three dimensions can exist containing less than four atoms of high quantivalence. If we extend our considerations to quadrivalent, quinquivalent, and sexivalent atoms, we shall at once see that great variety of structure is possible, although we may find it hard to say what form a given molecule really has. We cannot even affirm that any such molecule is actually of three dimensions, and not of only one or two; but we can assert that in these instances solidity of form is mathematically possible, just as we have alleged impossibility in other cases. Something more can safely be affirmed as to the relative position of the atoms in very complicated molecules. In such structures the univalent atoms can only exist at the exterior surfaces; or, in the case of plane molecules, they must lie around the periphery. That is, no univalent atom can be placed in the interior of any atomic cluster, since then it would be united with more than one other. We may even go a step further and assert the probability that, in general, in any complex molecule, the atoms of highest valency lie nearest the centre; being, as they are, the atoms from which radiate most numerously lines of attractive force. These views might easily be supported by some good evidence drawn from the phenomena of substitutions. Here we see that, as a rule, the univalent atoms of a molecule, those which must lie at its surface, are the easiest to substitute by other atoms; while, on the contrary, the elements of high valency in the interior of the structure are never directly replaced.

But all these considerations are based upon the idea that quantivalence is invariable. This idea is widely accepted, although not universally; and is one of the open questions in the chemistry of to-day. The moment we reject the conception, many, though not quite all, of the above conclusions fall to the ground. To my mind, no form of the theory of quantivalence as usually taught is

wholly acceptable. Of course I do not pretend to deny the importance of the vast number of analogies which quantivalence has classified; my difficulties are partly logical, and partly relate to experimental details. If we say that quantivalence is invariable, we are at once met by a large number of facts tending to prove variability; as, for example, the existence of the three chlorides of tungsten, WCl_4, WCl_5, and WCl_6; and the structural similarity and isomorphism of potassium perchlorate and permanganate. If, on the other hand, we claim that the valency of any element is capable of change, we must admit the same possibility for every element. Then, since all valencies are established by reference to hydrogen as unity, our standard becomes variable, or, in brief, no standard at all.

It must, however, be admitted that every atom has a maximum atom-fixing power, and that this power is probably different for different elements. We may then put the theory of quantivalence into a third form, and suppose that an elementary atom can exercise any valency whatever below its maximum limit. Now arises the question, which comes entirely within the scope of the present paper, what is the highest valency that any element can possibly have? Perhaps we may not be able to settle this question altogether, our estimate may be put too high; still, I believe it possible to find a limit which can never be exceeded, and which certainly has never been reached. At or below this limit all valencies must lie. Let us put the question in this form: how many univalent atoms can at the same time unite with one atom of maximum valency?

Probably the advocates of invariable quantivalence would scarcely admit the importance of this query. To a chemist of that school, carbon is completely saturated by four atoms of hydrogen, tungsten by six atoms of chlorine, and so on. But how do they know this? No hydrocarbon higher than CH_4 has been obtained; but how is it possible to assert that a CH_5, CH_{10}, or CH_{20}, may not yet be discovered? The assertion may be true, but its accuracy has certainly never been demonstrated. The believers in variable quantivalence, on the contrary, place no such limits in their way. With them an artiad may have any valency represented by an even, and a perissad any valency represented by an odd number. Some perissad elements particularly seem to have high values, running up even to valencies of nine, if not

over. These examples will serve to show in what a condition of vagueness and uncertainty the whole subject now is.

Now the complete solution of the problem before us requires a knowledge of some as yet unknown things. We know neither the size nor the shape of the atoms, their distances apart, nor their amplitude and velocity of vibration if they are moving. Were these questions answered, we should have good material to work upon; but, as it is, we must make a few assumptions. Let me state the main question again. How many atoms can at the same time be directly united to one atom of another kind? From the familiar law of gaseous volumes we may reasonably infer that all atoms are equal in size, though of different mass; but of their form we know absolutely nothing. Let us for a moment suppose that they are spherical, and that when chemically united they are in actual contact. The question then becomes—how many equal spheres can at the same time touch a central sphere of the same dimensions? If we admit fractions, the answer to this simple problem will be between twelve and thirteen; but, since fractional parts of atoms are out of consideration, the number we require must be twelve. If we suppose the spheres to be not in actual contact, but separated by equal spaces each from its lateral neighbors and from the central sphere, the number which can be thus grouped around the latter will still be twelve. If the atoms are tetrahedral, or cubic, or dodecahedral, or, in short, have any probable form other than spherical, the answer to our main problem would be something less than twelve. It is reasonable to assert, then, that no compound will ever be discovered containing, directly united with a single atom of one kind, more than twelve atoms of another. And if we measure the valency of any multivalent element by the number of univalent atoms with which its atom can unite, it is plain that no value over twelve is ever likely to be reached. Among compounds already known the highest valency thus directly measured is six—as in tungsten hexchloride; whether this may not be the absolute maximum we are, of course, unable to say.

But in the above argument there is one weak point. I have assumed that, in a molecule, the spaces separating adjacent atoms are all equal; whereas this can hardly be true. Take, for example, gun-cotton, which is formed from ordinary cotton by replacing three atoms of hydrogen each with the compound group

NO_2. Here we remove a few atoms, and put many atoms in their stead, without altering the external appearance or physical structure of the cotton in the least. The unavoidable inference is, that in this particular molecule, after the substitution, the interatomic spaces are not equal. Indeed, we could hardly assert in any case such an equality without at the same time assuming that the attraction between adjacent atoms was equal for all pairs of atoms in all parts of the structure. By such an assumption as this we should ignore all differences of mass among the atoms, and also deny the existence of anything like repulsive forces between them.

This question of interatomic spaces at once suggests another problem of great importance to a chemistry of three dimensions. Are the atoms of a molecule at rest relatively to each other, or are they in rapid motion? The latter view is almost universally adopted by modern physicists, and yet some facts in chemistry are hard to reconcile with it, or at least with the idea of vibratory motion. For example, the explanation of isomerism lies in the thought that a given number of atoms may be differently arranged so as to produce several dissimilar compounds. This conception gives each atom a definite place in a molecule from which it cannot wander without destroying the identity of the whole structure. The same remark holds true of the theory of compound radicals, in which not single atoms merely, but groups of atoms, are given fixed positions which cannot be much varied. It may be said, however, that our knowledge of isomerism and of compound radicals does not preclude altogether the motion of the atoms relatively to each other, but simply restricts that motion within extremely narrow limits. If we admit this, we get upon ground over which the theory of substitution sheds a very curious light. In the case of gun-cotton, already cited, each atom of hydrogen removed from the original cotton is replaced by the three atoms NO_2. Still the physical structure of the cotton is unchanged. If then we admit that the atoms of the molecule are rapidly vibrating, we must admit also that in this case of substitution the group NO_2 replacing hydrogen occupies just the same orbit that the latter substance travelled in, and moves with the same velocity. He would be a rash physicist who ventured to make such an assertion as the above. To say that the mutual atomic attractions of a molecule can produce the same velocity in hydrogen, and in a compound radical having forty-six times the mass of hydrogen,

would be wild indeed. Considerations like these lead me to suppose that the atoms of a molecule are at rest with regard to each other, although the molecule itself vibrates as a whole. Still, a mere rotatory motion of the atoms, involving no translation, might be admitted.

But it is easier to speculate upon difficult problems than it is to solve them. Indeed, my purpose in this paper has not been to settle anything, but rather to indicate that some generally accepted notions need reconstruction upon broader foundations. Let me briefly recapitulate. I have tried to show that upon the basis of quantivalence many compounds can be regarded as existing only in linear or plane molecules. It would be easy to discuss this question still further by taking up the theory of compound radicals; in which case I think I might show that a fair majority of all known substances are incapable of forming solid molecular structures. That is, I could have represented the chemistry of quantivalence as being essentially a chemistry of one and two dimensions, incompatible except in the minority of instances with the idea suggested by crystallography. Indeed, the very existence of crystalline bodies affords, to my mind, fair support to the notion that all molecules are of three dimensions. Should this ever be demonstrated, quantivalence, as now taught, would have to be abandoned. And yet, if the atomic theory be true, quantivalence in some form must be true also. Admitting this, I have tried to find the maximum of quantivalence, and have concluded that no element can ever have a valency higher than twelve. To this let me now add my firm belief that the valency of any given atom, in any given compound, depends upon the number and kind of atoms with which it is associated, and upon its position in the molecule. If we conceive of atoms as possessed not only of attractive but of repulsive forces as well, we can easily see that, when a number of mutually repellent atoms are held in place by the attraction of a central atom of some different kind, they must be situated in such a way that their tendency to repel each other cannot exceed the power which holds them in the cluster. The more closely they were crowded together the less stable the molecule would be. Perhaps we must by and by look to considerations of this sort for the true explanation of the analogies which quantivalence has classified.

Questions connected with the idea of maximum quantivalence

naturally brought up the subject of interatomic spaces, whose existence has hitherto been affirmed solely upon physical evidence. We have now seen that purely chemical testimony can demonstrate their existence also, and that they may be of various sizes within a single molecule. But chemistry and physics, here so harmonious, seemed to be at variance when we discussed the subject of atomic motions. This variance, real or seeming, is what led me to bring up the subject at all. It serves to show the necessity for concerted action between chemists and physicists, and that each class of workers should pay a little closer attention to the field cultivated by the other. Every problem brought up in this paper lies to a great extent within the borderland between physics and chemistry, and can only be solved by evidence drawn from both of these sciences. For my own part, I cannot claim to have contributed anything towards their solution; I have simply sought to point out curious lines of speculation, and profitable fields for future work.

ON CARBON DETERMINATIONS IN IRON AND STEEL. By JOHN W. LANGLEY, of Ann Arbor, Mich.

THE determination of the amount of carbon in iron and steel has long been recognized as an analytical process of great difficulty. To make an approximate estimate is easy, but when figures, accurate to the second decimal place of percentages, are the objects of inquiry, the number of apparently insignificant sources of error becomes so great that only the most minute and conscientious attention to details will insure a result which has any value at all when judged by the severe requirements which the engineer makes upon the metallurgist.

Not only is any process for the estimation of carbon intrinsically difficult, but no two methods will give the same results, and when the average of two series of analyses, conducted with equal care, but by different methods, are compared, they will usually differ from each other by more than one-tenth of one per cent.

In view of the attention which has recently been drawn to the connection between physical properties and chemical composition in the metals and alloys principally employed in the arts, and in which investigation steel, of course, plays a leading part, it becomes more than ever desirable for the analyst to select, out of the various means now at hand for the estimation of carbon, that which can be the most easily controlled, and by which the operator can with the greatest certainty assure himself that like conditions may be repeated at will.

In an ordinary determination of the carbon in an organic body, the possible variations in the method of procedure are not numerous, nor do they seem to have much influence on the final result. In the case of iron and steel, however, the circumstances are very different, for ninety-nine per cent. of metal must first be removed before the carbon can be in a state to be attacked, and then, too, it exists when separated from the iron, in two if not three different conditions, each of which has its influence on the process by which the element shall be finally brought into a form suitable for weighing.

At the outset we have to choose between two courses; first, the direct combustion of the alloy, and weighing the carbon as carbonic acid; second, the previous removal of the metal by some solution, and subsequent combustion of the insoluble residue. Of the first of these paths, it may be said, that though theoretically the straightest, it is in practice the least satisfactory, for the film of oxide of iron which immediately forms will protect the substance beneath it from further action, unless particles of extreme minuteness be operated on, and chemists who have paid a great deal of attention to this subject say that the more minutely divided is the metal, the greater will be the amount of carbon found. It has even been proposed to turn off fine shavings of hard steel by means of a diamond, as the best method of obtaining a sufficiently fine condition of metal. Now it is obvious that many samples of iron could not be mounted in a lathe and diamond turned, even if the costly tool necessary was always at hand, and filings, to quote an English author, "are lumpy little fragments which expose but a small surface in comparison with their mass."

The process by solution has the authority of many great names in its favor, but it is open to several sources of error. First, if

there is free acid present a portion of the carbon will escape as a gaseous or liquid hydrocarbon, and in fact, no one of the usual solvents, $Cu\ Cl_2$, $Cu\ So_4$, $Hg\ Cl_2$, can be maintained in a liquid which is absolutely neutral to litmus paper. Second, bromine and iodine attack the iron readily, but leave, as Eggertz has shown, a residue containing carbon, iodine, silicon, etc., in a form which is not affected by washing nor a heat under 250° C. If now this residue be burned, the iodine will escape and pass more or less completely into the absorption apparatus, and, of course, will tend to increase the apparent amount of carbon. Third, the character of the residue will differ according to the *rate* at which the metal has been dissolved. Caron and Grace Calvert have both shown that when steel is treated for a long time by very dilute acid, a residue was left which was much greater in quantity than when the action of the acid was promoted by warmth or concentration. Fourth, Caron first established the fact that the physical state of the metal had an influence on the quality and quantity of this carbonaceous residue. According to him one hundred parts of steel of cementation leave by treatment with acid:

	Residue.	Carbon.
Steel direct from converter . .	1,624	.825
" hammered	1,243	.560
" hardened	.240	.trace.

So that the same sample of steel which in its natural state shows nearly one per cent. of carbon may show, when tempered a trace only, and yet no one doubts that the same amount of carbon really exists in the above three samples.

In view of these facts the writer has given his preference to sulphate of copper as the solvent, notwithstanding the fact that it has been both strongly advocated and also energetically condemned long ago, for it does not contain any substance which can be retained by the insoluble residue, and is therefore free from the objections which may be raised against iodine, bromine and presumably chlorine and nitric acid. Then, too, it can always be used in the same degree of concentration in water, and the amount of free acid, which is always very minute, can be reduced to a constant quantity by previous digestion with oxide of copper. There is one detail, however, which the writer has found to be

important. If the metal is not finely divided and is introduced in a cold solution of copper, the attack will be very slow, and local action occurring here and there, the copper will be deposited in adherent masses, which oftentimes may be one-eighth of an inch thick and of the diameter of the beaker; as these are tough they cannot be completely broken up by stirring, and the carbon thus enveloped will not be completely burned. But if the metal is passed through a fine sieve, and introduced cold into the liquid, which is then gradually raised to 80° C. in a water bath, with frequent stirring, the whole residue will be in the form of a loose sponge, which can be filtered with the greatest ease in an ordinary funnel loosely plugged with asbestos, and as the copper so largely predominates, there is no trouble in detaching the mass from the funnel after drying. Indeed, this forms one of the chief advantages of the sulphate of copper process. The carbon being enveloped by the porous sponge is not disposed to run through any crevices in the filter, and the copper can be washed as easily as so much sand.

The carbonaceous residue thus obtained may be treated in two ways; first, by combustion at a red heat, second, by Ullgren's process, where it is introduced into a flask containing bichromate of potash and sulphuric acid. This latter method, though recent, has been much used, but the writer is obliged to confess that he has not been able to realize harmonious results from it. This is very likely owing to want of skill, but it may be there is a valid theoretical objection to the method. It was stated above that the amount of carbon in the residue varied according to the temper of the steel and the rate at which it was attacked. It has also been shown by several chemists that the untempered steel, and also that which was slowly dissolved, left a larger part of the carbon in the condition of *graphite* than did the samples otherwise treated. Now as Brodie has oxidized graphite into graphitic acid by liquid oxidants at 100° C. it would not seem unreasonable to suppose Ullgren's method liable to the same action, and hence that a part, or all, of the graphitic carbon, might not be converted into carbonic acid, but remain behind as graphitic acid, in which case it would fail, of course, of being weighed with the absorption apparatus.

This objection may not hold in practice; the writer is not prepared to prove it, but the necessity of carefully watching the

generating flask becomes quite onerous where a large number of analyses have to be made: he has, therefore, resorted to the method of combustion at a red heat, by modifying slightly the form of apparatus. A porcelain tube of about three-quarters of an inch internal diameter is placed in a furnace which will keep at least ten inches in length of tube up to a full yellow heat. A plug two inches in length is inserted in the anterior end; this plug is made by coiling up fine copper bell wire till it is just large enough to fit the tube closely; the interstices between the wires will always be large enough to allow of the passage of gas; air being now drawn through the apparatus the copper is deeply oxidized, and thus a filter of oxide of copper is produced, which, at a red heat, will oxidize any carbonic oxide or hydrocarbon which may pass over it.

To hold the matter to be burned a copper boat is provided which is easily made by folding up a piece of sheet copper; it should be about five inches long and when bent form a half cylinder with closed ends. A few small holes may be made through the bottom with a punch, in order to make the vessel porous. On the bottom of the boat a layer of asbestos is laid, and on this the mixed copper and carbon sponge is loosely placed.

The anterior end of the tube containing the wire plug being first heated, the boat is then introduced and the combustion conducted in the usual manner either in purified oxygen or air. Air seems to answer perfectly, only, of course, more of it must be used than of pure oxygen; the most convenient method is to draw the air through by means of a water aspirator, and at the rate of six litres an hour. Operating in this way I have not found any difficulty in oxidizing the carbon completely, even the graphite. This is probably from two reasons: first, the heat is a full yellow, much more than a glass tube could bear; secondly, the carbon being in a state of molecular division and surrounded on every side by particles of metallic copper, is sure to be burned as soon as the copper itself becomes oxidized.

When once this apparatus is mounted it demands very little attention; the porcelain tube will last from ten to twenty times, and by having two boats one may be withdrawn and the other inserted without cooling the tube, so that two combustions, including the weighings and calculations, may be made inside of three hours. The copper boats, if made of ordinary thin metal,

will last five times before they become entirely oxidized through. As showing the result of the above method, which has been used during the past year and a half, I will venture to quote a few out of a large number of analyses.

		Carbon.		Carbon.		Carbon.		Carbon.
	A	1·065	B	·843	C	·841	D	·896
		1·051		·828		·841		·871
Difference		·014		·015		·000		·025

A, B, C, D, being different samples of steel. After making an aggregate of over sixty combustions, the maximum departure from the mean in various samples has been three hundredths of one per cent., and the average departure from the mean is a trifle over one hundredth, or one part in ten thousand of the metal operated on.

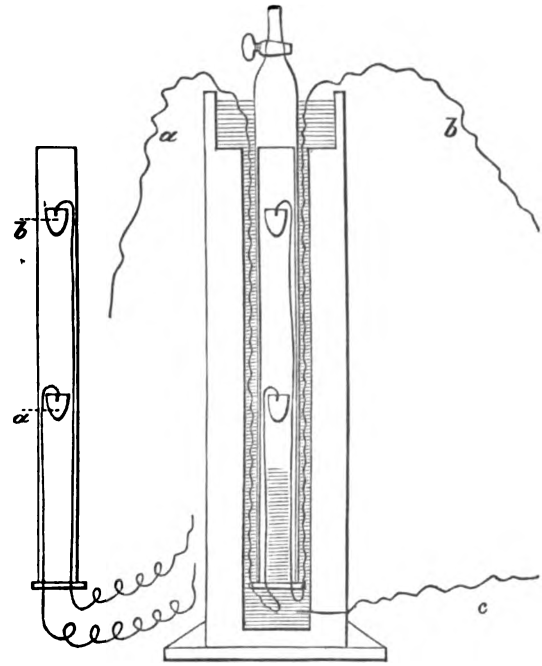
To recapitulate, the method described above consists in attacking the alloy, previously pulverized and *sifted*, by a solution of sulphate of copper, washing the mixed copper and carbon on a funnel plugged with asbestos, and finally burning the entire mass in a stream of oxygen or air in a porcelain tube maintained at a much higher temperature than can possibly be used with Bohemian glass.

An Improvement in Bunsen's Method for Specific Gravity of Gases. By T. C. Mendenhall, of Columbus, Ohio.

Bunsen's method consists in taking the time occupied in the flow of a given volume of a gas through a small opening in a thin plate of platinum. The time is ascertained by noting the instant of the passage of a line drawn upon a glass float, which moves upon the surface of the mercury in the cistern, behind a fixed line drawn upon the gas chamber. In the improvement it is proposed to dispense with the float and measure the time by means of an electric chronograph — the circuit being closed at two points —

separated by a convenient distance, within the chamber. Figs. 1 and 2 show how an ordinary form of the apparatus has been modified.

Fig. 1. Fig. 2.



A thin hard board is made of a proper length and width to fit closely in the tube containing the gas; *a* and *b* are windows cut in it, and in which are platinum points turned downward, and connected by means of insulated wire with the outside of the mercury cistern. A shoulder is made upon the lower end of the board to insure that it always reaches the same point in the tube. Fig. 2 represents the same board as fitted in the gas tube and that immersed in the mercury cistern. A vertical section is shown, *a* and *b* are the conducting wires as before, and *c* is a wire in continuous contact with the mercury within the cistern. The stopcock being opened the mercury in rising closes the current successively between *c* and *a* and *b*. Thus the beginning and end of the time may be marked by a chronograph or by a bell magnet;

in the latter case, the operator can give his attention entirely to taking the time from a clock or watch.

It will be seen that much greater accuracy as well as greater ease is attainable by this method than by the use of a float. It is obvious that a simple arrangement will be to fuse the platinum wires in the sides of the gas chamber. The most convenient device, perhaps, is that of using the ordinary gas tube with a new mercury cistern—in the centre of which rises a slender rod containing the platinum points—the wires from which are carried out through the side or bottom of the cistern.

Comparative Determinations of the Solubilities of Alkaloids in Crystalline, Amorphous and Nascent Conditions: Water-washed Solvents being used. By Albert B. Prescott, of Ann Arbor, Mich.

The few determinations here reported were made with the desire to obtain further data as to the power of solvents when used to extract alkaloids from water solutions or moist residues. The separations of alkaloids, by treating their salts, in water solution or in moist residue, at once with alkali and with solvents, are already found of great service in proximate analysis. The use of ether after alkali, as proposed by Stas in 1851, with the previous ether washing of the acid material as proposed by Otto in 1856; also the use of chloroform instead of ether, as proposed by Rodgers and Girdwood in 1856, and the use of amylic alcohol in the way of Otto's modification, as proposed by Uslar and Erdmann in 1861,[1] have become familiar from their value in forensic analysis. More recently, Dragendorff has presented methods for the use of various solvents, particularly chloroform, amylic alcohol, benzole, and "petroleum ether," each being applied alternately in acid and alkaline aqueous solutions, for various analytical purposes, especially the separation of alkaloids from

[1] Anal. d. Chem. u. Pharm., 120, 121: Zeitsch. f. Analyt. Chem., i. 267.

plant constituents and the systematic separation of alkaloids from each other.[3]

In most of these operations the solvents are necessarily saturated with water; and ether, chloroform and amylic alcohol hold quantities of water sufficient to affect their solvent power to a considerable extent. At the same time these three solvents can readily be obtained free from ethylic alcohol, and the ether and chloroform free from acids, the impurities occurring in their commercial state and largely varying their solvent power, simply by washing with water. In other words, we have in water-washed ether, chloroform and amylic alcohol, cheap, convenient and uniform grades of these solvents, nearly or quite free from all impurities except the water, which is unavoidably present in the analytical processes to be provided for.

It is desirable to know how much influence the amorphous condition and that of recent liberation from salt have upon the adhesive force of alkaloids for these water-washed solvents; so that we may understand the degree of supersaturation attained when dissolving in the nascent or amorphous condition.

The *washed ether* used was neutral to test paper, and of sp. gr. 0·7290, at 15° C. Before washing, it was acid and of sp. gr. 0·7477, at 15° C.

The *washed chloroform* was neutral, and of sp. gr. 1·4953, at 15° C. In washing chloroform, the last agitation was made and the water drawn off at 0° C., by which means more perfect separation is effected. It was slightly turbid when below 16° C., but clear when above that temperature. If washed at 18° to 20° C., it would be turbid below 24° C.

The *washed amylic alcohol* was of sp. gr., 0·8316, at 15° C.

The *washed benzole* was of sp. gr. 0·8766, at 15° C.; and boiled at 89° C.

The *morphia* was purified by digesting and washing with the solvents employed respectively. The *cinchonia* was washed for some time on a filter with ammonia of sp. gr. 0·96; then dried and well washed with ether and dried again.

Except as otherwise stated, the solvents were applied at their

[3] Pharm. Zeitsch. für Russland, 1866, Heft. 2, and 1867, Heft 10; Zeitsch. f. Analyt. Chem., vi, 300, and vii, 52.
Zeitsch. f. Analyt. Chem., viii, 240 (1869).
Beitrage zur Gericht. Chem. Organ, Gifte, 1872.
Die Chem. Werthbestimmung einiger Starkwirkender Droguen, 1874.

boiling points for five minutes; when they were turned upon the filter. To dissolve in the "nascent condition," a sulphuric acid solution was warmed in a large test-tube, mixed with the solvent and the mixture warmed to the boiling point of the solvent, then made *slightly* alkaline with ammonia and shaken, and kept warm for five minutes, then turned upon the filter. The filtered solutions were received in a tared specific gravity bottle; the bottle being stoppered as soon as possible and the weight of bottle and contents taken. The solution was then turned into a thin tared beaker, the bottle well rinsed with portions of the solvent into the beaker, and the liquid evaporated on the water-bath, at a suitable temperature, and the weight of the residue taken. The weight of residue, deducted from that of the solution, gives the weight of the solvent. From five to ten grammes of the solvent were used. For solubilities of morphia, two or more trials were made for each determination, the mean being given. For solubilities of cinchonia, but one trial was made in each determination.

Morphia: number parts of water-washed solvent required for one part of alkaloid.

	Ether.	Chloroform.	Amylic Alcohol.	Benzole.
Crystallized	6148	4379	91	8930
Amorphous	2112	1977	—	——
Nascent	1062	861	91	1997

Cinchonia: number parts water-washed solvent required for one part.

	Ether.	Chloroform.	Amylic Alcohol.	Benzole.
Crystallized	719	828	—	——
Amorphous	563	——	40	531
Nascent	526	178	22	376

Crystallized morphia treated fifteen minutes with washed chloroform at 25° C., required 9770 parts of the solvent; treated with boiling chloroform, and allowed to deposit for twelve hours and then filtered, held 6209 parts of the solvent.[3]

Nearly all the solutions deposited alkaloid on standing a short

[3] Wormley gives 6550 as ratio of chloroform (not washed) to morphia in saturated solution: *Micro-chemistry of Poisons*, 471.

Hager, an authority generally exact, gives morphia as soluble in about 90 parts of chloroform: *Untersuchungen*, II, 159.

time, though most of the filtrates remained clear for five or ten minutes.

When the acid solution of morphia was made alkaline with a large excess of potassa (a ready solvent of the alkaloid) it required 5656 parts of chloroform instead of 861. The writer has from time to time observed that alkalies which redissolve the alkaloids, in so doing, measurably prevent extraction upon Stas' plan. Doubtless, the best results in these cases would follow the use of measured quantities of standard solutions of the acid employed to salify and the alkali employed to liberate the alkaloidal material.

The residues of morphia, from ether, chloroform and benzole, were amorphous; from amylic alcohol crystalline. The residues of cinchonia from ether and from amylic alcohol were crystalline, from chloroform and from benzole amorphous.

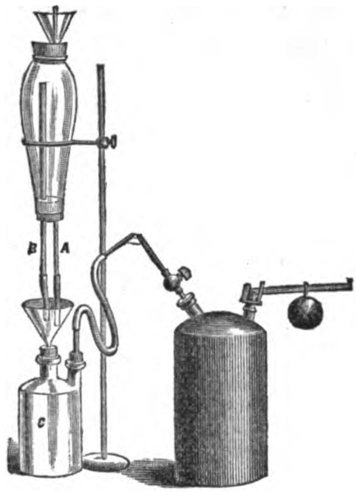
Determinations of solubilities, when the ratio of solvent to solid is very large, must necessarily be approximate rather than precise, even when the stable, saturated solutions are determined. And when the instable, *supersaturated solutions* are undertaken, it is evident that variations must be greater. The time taken in filtration, for instance, and the atmospheric temperature during filtration, must affect the results. The effect of temperature of the solvent, when applied to the alkaloid at the moment of its liberation, the writer has not yet investigated.

Rapid and Automatic Filtration, with Description of Apparatus. By Thad. M. Stevens, of Indianapolis, Ind.

Among the most useful principals to the analytic chemist are those of rapid and automatic filtration. Several appliances have been brought into use for the accomplishment of such a process. As to rapid filtration, none have any degree of value that are not based upon the idea of exhaustion of the vessel to contain the filtrate. "Bunson's pump," so-called, is the most efficient of all in use, but there are several practical objections thereto. First, its cost and fragility prevents its universal adoption and is productive of troubles; apart from this it requires a plentiful supply of water, such as is not available in the smaller laboratories at

least. Such objections practically shut off seven-eights of those who would be benefited from its use.

Feeling the need of some more simple apparatus, one that could be obtained by all, we have applied the well-known power of steam to the purpose of producing exhaustion, in the same way that it is applied in the common atomizers. A boiler holding about one pint is used; with this we can cause enough exhaustion to answer in all ordinary cases.



Apparatus for Rapid and Automatic Filtration. A. Tube with rubber tip by which the filter is supplied. B. Tube with rubber tip by which the air is supplied to vessel containing the fluid. C. Wolff bottle to contain filtrate.

By reference to the cut the plan will be fully explained. The boiler has attached to it the atomizing tube. The lower portion of the latter unites by a rubber tube with the vessel (C) to be exhausted and that is to contain the filtrate; in this case it is a Wolff bottle. Into one opening of this is inserted a cork through which a funnel is passed; this completes the rapid filtration part of the plan. As the fluid is poured into the filter that is placed in the funnel inserted into the vessel (C) and exhaustion produced, by the atomizer, the rapidity of filtration is increased from four to six fold, sufficient for all practical purposes; the adjustment of the filter into the funnel is similar to that of Bunson's, a platinum cap being placed at the apex to prevent rupture. What we have found to answer quite as well is a point or cap of artificial parchment paper, applied in the same way.

The automatic portion of the apparatus shown may be formed out of a lamp chimney and may be of various sizes according to the amount of fluid to be filtered. A cork, of gutta-percha in preference, is fitted into either extremity of the chimney; into the lower cork two glass tubes are inserted, the one stopping at the inner surface of the cork, the other passing up to within a short distance of the other cork. At the lower extremity of these two tubes are attached two pieces of rubber tubing, the one upon the tube (a) to be about three inches in length, the other two and a half inches, through the cork; at the larger and upper extremity of the chimney, a small funnel is passed through which the fluid to be filtered is poured, the rubber tubing below being closed by a small clamp in the meanwhile; when the fluid has been introduced the tube of the funnel is closed by a plug of soft wood or rubber, thus the chimney is air tight. Now if this is supported by a retort stand or clamp, and placed so that the rubber tubing (a) and (b) be within the filter, and the end of (b) one-fourth of an inch below the upper edge thereof, and the clamp removed, then the fluid will pass out of the tubing (a) until the end of the other tubing (b) is closed by the escaped fluid. This will, of course, take place before the filter is quite filled, and at that instant the flow will cease until this tube is again rendered pervious by the escape of the fluid through the filter. The fluid cannot overflow the filter at any time, and the filtration can go on until all the fluid has passed without any further attention being bestowed upon it. Again, the continued agitation of the liquid that takes place in the chimney, thoroughly washes the precipitate, so that when the operation of filtration is once completed no further trouble is experienced, as in cases where this plan is not adopted. In conclusion, we will say that the practical working of this mode of rapid and automatic filtration is satisfactory. The gross cost need not exceed ten dollars. The exhaustion of the vessel (C) might be produced by the substitution of clock-work for the steam atomizer, or electricity could be utilized as the motive power.

TITLES OF COMMUNICATIONS.

The following titles of papers read in Section A include those accepted by the committee for publication in full, or by abstract, but of which the authors have failed to send copy, as well as those which the committee decided should be printed by title only:

On the Omission of Dynamical Quantities from Chemical Formulæ. By H. F. Walling, of Boston, Mass.

On Certain New Tungsten Compounds. By Albert R. Leeds, of Hoboken, N. J.

Descriptive Geometry. By S. Edward Warren, of Boston, Mass.

Note on Colorado Tellurium. By F. W. Clarke, of Cincinnati, Ohio.

Tides of New York Harbor. By Wm. Ferrel, of Washington, D. C.

Algebraic Curves Expressed in Trigonometric Equations. By H. A. Newton, of New Haven, Conn.

Transformation of Curves from Algebraic to Transcendental. By H. A. Newton, of New Haven, Conn.

On Certain Transcendental Curves. By A. W. Phillips, of New Haven, Conn.

Geometrical Representation of Certain Diophantine Problems. By H. A. Newton, of New Haven, Conn.

On the Relative Intensity of the Broken Lines of Metallic Spectra. By George F. Barker, of Philadelphia, Pa.

A New Vertical Lantern Galvanometer. By George F. Barker, of Philadelphia, Pa.

Adjustment of the Gregorian Calendar. By E. B. Elliott, of Washington, D. C.

On Otto's Method of Estimating Phosphoric Acid in Presence of Iron and Aluminium. By S. W. Johnson, of New Haven, Conn.

Apparatus for Fat Extraction. By S. W. Johnson, of New Haven, Conn.

Composition of Corn Fodder and Yield per Acre. By S. W. Johnson, of New Haven, Conn.

Composition of the Sweet Potato. By S. W. Johnson, of New Haven, Conn.

On Thorpe's Method of Estimating Nitric Acid. By S. W. Johnson, of New Haven, Conn.

Description of an Apparatus for the Automatic Determination of Atmospheric Resistance. By G. W. Hough, of Albany, N. Y.

A Convenient Instrument for Showing the Absorption of Hydrogen Gas by Palladium. By J. Lawrence Smith, of Louisville, Ky.

Some Remarks on Graphitic Oxyde as prepared from the Graphites of the Sevier Co. and Dekalb Co. Meteorites. By J. Lawrence Smith, of Louisville, Ky.

Exhibition of Clamond's Thermo-electric Pile with some Remarks on its Construction. By J. Lawrence Smith, of Louisville, Ky.

Notice of an undescribed Meteorite that fell in Wisconsin in 1865. By J. Lawrence Smith, of Louisville, Ky.

Exhibition of a large quantity of Cæsium Alum with some Remarks on its Preparation. By J. Lawrence Smith, of Louisville, Ky.

On Certain Precipitates containing Chloride of Silver. By F. W. Clarke, of Cincinnati, Ohio.

Temperature of two Deep Bores in Indiana. By E. T. Cox, of Indianapolis, Ind.

ON THE DISSOCIATION OF WATER BY HEAT AS A CAUSE OF STEAM BOILER EXPLOSIONS. By L. BRADLEY, of Jersey City, N. J.

MODE OF PRESENTING THE INTERESTS OF OUR HIGHER EDUCATIONAL INSTITUTIONS AT THE CENTENNIAL EXHIBITION AT PHILADELPHIA, IN 1876. By FRANKLIN B. HOUGH, of Lowville, N. Y.*

THE GERMAN ARCTIC EXPEDITION OF 1869–1870, AND ITS RESULTS. By W. W. WHEILDON, of Concord, Mass.†

THE EARLY DUTCH AND ENGLISH EXPLORATIONS OF THE ARCTIC REGIONS. By W. W. WHEILDON, of Concord, Mass.†

*Read in General Session. †Read by title in General Session.

PART II.

SECTION B,

NATURAL HISTORY.

ADDRESS

OF

J. W. DAWSON.

Of the leaders in Natural Science, the guides and teachers of some of us now becoming gray, who have in the past year been stricken by death from the roll of workers here, and have entered into the unseen world, two rise before me with special vividness on the present occasion:—Lyell, our greatest geological thinker, the classifier of the Tertiary rocks, the summer up of the evidence on the antiquity of man; but above all the founder of that school of geology which explains the past changes of our globe by those at present in progress; and Logan, the careful and acute stratigraphist, the explorer and establisher of the Laurentian system, and the first to announce the presence of fossil remains in those most ancient rocks. What these men did and what dying they left undone, alike invite us to the consideration of the present standpoint of Geological science, the results it has achieved and the objects yet to be attained; and I propose accordingly to select a small portion of this vast field and to offer to you a few thoughts in relation to it, rather desultory and suggestive however, than in any respect final. I shall therefore ask your attention for a short time to the question—"What do we know of the origin and history of life on our planet?"

This great question, confessedly accompanied with many difficul-

ties and still waiting for its full solution, has points of intense interest both for the Geologist and the Biologist. In treating of it here, it will be well, however meagre the result, to divest it of merely speculative views, and to present as far as possible the actual facts in our possession, and the conclusions to which they seem to point.

"If," says that greatest of uniformitarian geologists, who has so recently passed away, "the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitesimal portion of eternity." Yet to our limited vision, the origin of life fades away in the almost illimitable depths of past time, and we are ready to despair of ever reaching, by any process of discovery, to its first steps of progress. At what time did life begin? In what form did dead matter first assume or receive those mysterious functions of growth, reproduction and sensation? Only when we picture to ourselves an absolutely lifeless world, destitute of any germ of life or organization, can we realize the magnitude of these questions, and perceive how necessary it is to limit their scope if we would hope for any satisfactory answer.

I shall here dismiss altogether that form in which these questions present themselves to the biologist, when he experiments as to the evolution of living forms from dead liquids or solids—an unsolved problem of spontaneous generation which might alone occupy the whole time of this Section. Nor shall I enter on the vast field of discussion as to modern animals and plants opened up by Darwin and others. I shall confine myself altogether to that historical or palæontological aspect in which life presents itself when we study the fossil remains entombed in the sediments of the earth's crust, and which will enable me at least to show why some students of fossils hesitate to give in their adhesion to any of the current notions as to the origin of species. I may also explain that I shall avoid, as far as possible, the use of the term evolution, as this has recently been employed in so many senses as to have become nearly useless for any scientific purpose, and that when I speak of creation of species, the term is to be understood not in the arbitrary sense forced on it by some modern writers, but as indicating the continuous introduction of new forms of life under definite laws, but by a power not emanating from within themselves, nor from the inanimate nature surrounding them.

If we were to follow the guidance of those curious analogies which present themselves when we consider the growth of the individual plant or animal from the spore or the ovum, and the development of vegetable and animal life in geological time—analogies which, however, it must be borne in mind can have no scientific value whatever, inasmuch as that similarity of conditions which can alone give force to reasoning from analogy in matters of science, is wholly wanting—we should expect to find in the oldest rocks embryonic forms alone, but of course embryonic forms suited to exist and reproduce themselves independently.

I need not say to palæontologists that this is not what we actually find in the primordial rocks. I need but to remind them of the early and remarkable development of such forms as the Trilobites, the Lingulidæ and the Pteropods, all of them highly complex and specialized types, and remote from the embryonic stages of the groups to which they severally belong. In the case of the Trilobites, I need but refer to the beautiful symmetry of their parts both transversely and longitudinally, their division into distinct regions, the complexity of their muscular and nervous systems, their highly complex visual organs, the superficial ornamentation and microscopic structure of their crusts, their advanced position among Crustaceans, indicated by their strong affinities with the Isopods. All these characters give them an aspect far from embryonic, while, as Barrande has pointed out, this advanced position of the group has its significance greatly strengthened by the fact that in early primordial times we have to deal not with one species but with a vast and highly differentiated group, embracing forms of many and varied subordinate types. As we shall see, these and other early animals may be regarded as of generalized types but not as embryonic. Here then meets us at the outset the fact that in as far as the great groups of annulose and molluscous animals are concerned, we can trace these back no further than in a period in which they appear already highly advanced, much specialized and represented by many diverse forms. Either therefore these great groups came in on this high initial plane, or we have scarcely reached half way back in the life history of our planet.

We have here, however, by this one consideration attained at once to two great and dominant laws regulating the history of life. First, the law of continuity, whereby new forms come in

successively, throughout geological time, though as we shall see with periods of greater and less frequency. Secondly, the law of specialization of types, whereby generalized forms are succeeded by those more special, and this probably connected with the growing specialization of the inorganic world. It is this second law which causes the parallelism between the history of successive species and that of the embryo.

But there are great masses of strata known as Lower Cambrian, Huronian, Laurentian, which have made as yet few revelations as to the life which may have existed at the time of their deposition. In these rocks we know the problematical *Aspidella* of Billings from Newfoundland, the worm-burrows or Scolithus-like objects which occur in the Pre-silurian rocks of Madoc, the *Eozoon Bavaricum* of Gumbel, and the *Eozoon Canadense*, first made known by Logan, in the Laurentian of Canada. The first of these names represents a creature that may have been a mollusk, allied to Patella, or some obscure form of crustacean. The cylindrical holes called worm-burrows, are of course quite uncertain in their reference. They may represent marine worms in no respect different from those now swarming on our shores, or sponges, or corals, or sea-weeds. In any case they afford little help in explaining the teeming life of the primordial seas, and we can only hope that the vast thickness of sediments which has afforded these few traces of life may prove more fertile in the future. One slender beam of light in the darkness is, however, afforded by the *Eozoon Bavaricum* of Gumbel. If truly a fossil, this creature is closely connected with the still older *Eozoon* of the Laurentian. It therefore points backward to what is to us the dawn of life, but has no close link of connection with the succeeding fauna. On the other hand *Aspidella* and *Scolithus* may be held, if obscurely, to point forward. Thus the Huronian and early Cambrian become a period of transition from the Protozoa of the Laurentian to the higher marine life that succeeds—a passage to be more fully explained perhaps, and its great gaps filled by future discoveries; but which may, as in some later periods, be complicated with a contemporaneous transition from oceanic to shallow-water conditions in the localities open to exploration.

It will be observed that I take for granted the animal nature of Eozoon. If we reject this, we stand face to face with the bare, bald mystery of the abrupt manifestation of the Primordial fauna,

without even so much of preparation as may be supposed to arise from the previous appearance of Protozoa.

How then stand the facts as to the Proto-foraminifer? In answering this question, we should, I think, endeavor to divest ourselves of certain prejudices, and to give due weight to some probabilities and analogies which may in one way or another sway our opinion.

First, we must be prepared to find that those old crystalline rocks which we call Laurentian, have no real affinity with intrusive granites and other igneous masses, but are most nearly allied to modern sedimentary deposits. That the original chemical character of some of these ancient sediments may have differed to some extent from that of more modern sediments I do not doubt. Yet it is true that the more common of them, as the gneisses, diorites and mica-schists, consist of precisely the same elements which now appear in modern clays and sands, and that where local alteration has affected more modern rocks, we see these passing by insensible gradations into similar metamorphic beds. Farther when the old crystalline rocks are subjected to subaerial disintegration, they resolve themselves again into the most common sedimentary materials.

Another consideration here is the unequal manner in which sediments become altered according to their composition, and to the extent to which they are permeable by heated waters and vapors. For this reason, contiguous beds of rock will often be seen to differ very much in the degree of their alteration. Farther, some beds, and more especially limestones, continue to retain traces of organic structure long after these have perished from neighboring beds of different chemical composition. More especially when, in limestone, the cavities and pores of the fossils have been penetrated with other mineral matter, it would appear that nothing short of actual fusion will serve to obliterate them. Again, microscopic structures are often well preserved when the external forms have been lost, or are completely inseparable from the matrix, and in the present state of microscopical science there is little danger that in such specimens any experienced microscopist will fail to perceive the difference between organic and crystalline structures.

Having freed ourselves from misconceptions of these kinds, we may next turn to certain presumptions established by the consti-

tution of the Laurentian rocks, and the minerals contained in them.

The limestones of the Laurentian system are of great thickness and of vast geographical extent. Sir W. E. Logan has traced and measured three principal bands of these limestones, ranging in thickness from 60 to 1,500 feet, and traceable continuously in one district of Canada for more than one hundred miles, while their actual horizontal area must be enormously greater than this distance would indicate. These limestones are also associated with gneissose and schistose beds, exactly in the same way in which Palæozoic limestones are associated with sandstones and shales; and some of them are ordinary limestones, while others are more or less dolomitic, in which also they resemble the palæozoic limestones. Every geologist knows that the beds which in the succeeding geological periods are the representatives of these Laurentian limestones, are not only fossiliferous, but largely composed of the dèbris of oceanic organisms, and that it is to the purer and more crystalline beds that this statement most fully applies. May we not reasonably infer that the great Laurentian limestones are of similar origin.

One feature of these beds which has sometimes received a very different interpretation, I would here place in this connection. It is the association of Hydrous Silicates, and especially of Serpentine and Loganite, with the limestones, an association not universal but by no means uncommon in the Laurentian, and which may now be affirmed to occur throughout the whole series of marine organic limestones, up to the chalky foraminiferal mud now accumulating in the depths of the ocean. It is true that the silicates found in different formations differ somewhat in composition, but Dr. Sterry Hunt has shown that the Serpentines, Jollite, Loganite and the various Glauconites constitute a single series, whose members graduate into each other, and some of the modern Glauconites are not essentially distinct from the most ancient Serpentine.

This association is not accidental. It arises in the first place from the facility afforded for the combination of Silica with bases, arising from the presence of organic matter in the sea-bottom, and secondly from the abundance of soluble Silica in the hard parts of Diatoms, Radiolarians and Sponges, while these form the chief food of animals building their own skeletons of Carbonate of Lime, and consequently having no need of Silica. In this

point of view the Hydrous Silicates may be regarded as a sort of coprolitic matter, rejected by Foraminifera and other humble marine animals having calcareous skeletons. I hold, therefore, that the association of Serpentine and Loganite with the Laurentian limestones affords an additional reason for regarding them as organic, while it also explains the favorable conditions in which Foraminifera exist for the permanent preservation of the structures of their tests.

But again, there are vast quantities of Carbon in these limestones and the associated beds. The quantity of carbon in some large regions of the Lower Laurentian in Canada, is, as I have elsewhere shown, comparable with that in similar thicknesses of the Carboniferous system. But what geologist refers the carbon of the Palæozoic rocks to any other than an organic origin. True it is that this carbon of the Laurentian is in the state of graphite and destitute of organic structure; but this applies to similar material in other altered rocks, for example, to the graphitic shales of the Silurian of Eastern Canada and to the coal of Rhode Island.

Lastly, ought we not to attach some value to that generalization of Dr. Sterry Hunt, which affirms that the grand agent in the reduction and solution of the Peroxide of Iron has been organic matter. In this case what incalculable quantities of perished carbonaceous matter must be represented by the great beds of Magnetite in the Laurentian.

If, then, it is not unreasonable to believe that the Laurentian limestones may be of organic origin, the next question that occurs relates to the state of preservation in which the remains of such supposed organisms may occur. It would be conceivable that the process of crystalline rearrangement of particles might have proceeded so far as entirely to obliterate all traces of organic form or structure; but judging from other cases of altered limestones, this would be scarcely likely. In such limestones it is true, the fossils are often so obscure as to make little appearance on a fresh fracture of the stone, but they may present themselves distinctly on the weathered surfaces, in consequence of some difference either in resisting power or hardness, between the fossil and the matrix. In some cases also they can readily be developed by the action of an acid, and still more frequently their microscopic textures remain when the external forms are entirely concealed. There are

few crystalline marbles, once fossiliferous, that do not exhibit indications of their true nature in one or other of these ways.

It was precisely in the ways above indicated that *Eozoon Canadense* was first brought to light. The casts of its flattened chambers filled with Serpentine, Loganite or Pyroxene, project from the weathered surfaces of the Laurentian limestones, exactly as silicified Stromatoporæ do in the Silurian. Such specimens, collected by the explorers of the Canadian Survey, first gave the idea that there were fossils in these ancient rocks, and the microscope soon confirmed the indications afforded by external form, and demonstrated the place of the organism in the animal kingdom.

Into the description of the forms and structures of Eozoon it would be out of place to enter here. The details of these may be found in publications specially devoted to its description. I would merely insist on the entire conformity of the microscopic structures as I have myself examined and described them, and as they have been farther scrutinized by Dr. Carpenter and others best fitted to judge, with those of the calcareous tests of Foraminifera, and especially of the Nummuline group, and on the harmony of these structures with what the general considerations already referred to would lead us to expect.

It is, however, appropriate to our present subject, to inquire as to the position of Eozoon in the scale of animal existence, and its possible relations to preceding or succeeding types of life. With reference to these questions, it is obvious that we can predicate nothing as to the relation of our proto-foraminifers to the varied life of the Primordial or to any other group of animals than its own. We do not know that Eozoon was the only animal of its time. It may be merely a creature characteristic, like some of its successors, of certain habitats in the deep sea. Foraminifera have existed throughout the whole of geological time; but we have no positive evidence that any animal of this class has ever been transmuted into any other kind of creature. These considerations oblige us to restrict our inquiries to the relation of Eozoon to other forms of Foraminiferal life. We may the more excusably take this ground sinee even Hæckel, in his gastrula theory, has so strenuously maintained the distinctness of the Protozoa from all higher forms of life. Viewed in this way, we find that the proto-foraminifer was the greatest of all in point of magnitude, one of the most complex in regard to structure, compre-

hensive in type, as connecting the groups now recognized as the Nummulines and the Rotalines, and if inferior in anything only in less definiteness of habit of growth, a character in which it is paralleled by the sponges and other groups of higher rank. Thus if Eozoon was really the beginning of Foraminifers, this, like other groups in later times, appeared at first in one of its greatest and best forms, and its geological history consists largely in a gradual deposition from its high place as other and higher types little by little took its place; for degradation as well as elevation, belongs to the plan of nature. Eozoon here brings under our notice another phase of a creative law, which is corroborated by other forms of life in the succeeding periods. It is this. New types do not usually appear in their lowest forms, but in somewhat high if generalized species. The fact that Foraminifera, allied to Eozoon, have continued to exist ever since, introduces us to still another, namely, that though species and individuals die, any large group once introduced is very permanent, and may continue to be represented for the remainder of geological time.

But let us leave for the present the somewhat isolated case of Eozoon, and the few scattered forms of the Huronian and early Cambrian life, and go on further to the Primordial fauna. This is graphically presented to us in the sections at St. David's in South Wales, as described by Hicks. Here we find a nucleus of ancient rocks supposed to be Laurentian, though in mineral character more nearly akin to our Huronian, but which have hitherto afforded no trace of fossils. Resting unconformably on these is a series of partially altered rocks, regarded as Lower Cambrian, and also destitute of organic remains. These have a thickness of almost 1,000 feet, and they are succeeded by 3,000 feet more of similar rocks, still classed as Lower Cambrian, but which have afforded fossils. The lowest bed which contains indications of life is a red shale, perhaps a deep-sea bed, and possibly itself of organic origin, by that strange process of decomposition or dissolution of foraminiferal ooze, described by Dr. Wyville Thomson as occurring in the South Pacific. The species are two *Lingulellæ*, a *Discina* and a *Leperditia*. Supposing these to be all, it is remarkable that we have no Protozoa or Corals or Echinoderms, and that the types of Brachiopods and Crustaceans are of comparatively modern affinities. Passing upward through another 1,000 feet of barren sandstone, we reach a zone in which no less than

five genera of Trilobites are found, along with Pteropods and a sponge. Thus it is that life comes in at the base of the Cambrian in Wales, and it may be regarded as a fair specimen of the facts as they appear in the earlier fossiliferous beds succeeding the Laurentian. Taking the first of these groups of fossils, we may recognize in the *Leperditia* an ostracod Crustacean closely allied to forms still living in the seas and fresh waters. The *Lingulellæ*, whether we regard them as molluscoids, or with our colleague, Professor Morse, as singularly specialized worms, represent a peculiar and distinct type, handed down, through all the vicissitudes of the geological ages, to the present day. Had the Primordial life begun with species altogether inscrutable and unexampled in succeeding ages, this would no doubt have been mysterious; but next to this is the mystery of the oldest forms of life being also among the newest. One great fact shines here with the clearness of noon-day. Whatever the origin of these creatures, they represent families which have endured till now in the struggle for existence without either elevation or degradation. Here again we may formulate another creative law. In every great group there are some forms much more capable of long continuance than others. Lingula among the Brachiopods is a marked instance.

But when, with Hicks, we surmount the mass of barren beds overlying these remains, which from its unfossiliferous character is probably a somewhat rapid deposit of arctic mud, like that which in all geological time has constituted the rough filling of our continental formations, and have suddenly sprung upon us five genera of Trilobites, including the fewest-jointed and most many-jointed, the smallest and the largest of their race, our astonishment must increase, till we recognize the fact that we are now in the presence of another great law of creation, which provides that every new type shall be rapidly extended to the extreme limits of its power of adaptation.

Before considering these laws, however, let us in imagination transfer ourselves back to the Primordial age, and suppose that we have in our hands a living *Plutonia*, recently taken from the sea, flapping vigorously its great tail, and full of life and energy; an animal larger and heavier than the modern king-crab of our shores, furnished with all that complexity of external parts for which the crustaceans are so remarkable, no doubt with instincts and feelings and modes of action as pronounced as those of its

modern allies, and if Woodward's views are correct, on a higher plane of rank than the king-crab itself, inasmuch as it is a composite type connecting Limuli with Isopods. We have obviously here in the appearance of this great crustacean, a repetition of the facts which we met with in Eozoon; but how vast the interval between them in geological time, and in zoological rank. Standing in the presence of this testimony, I think it is only right to say that we possess no causal solution of the appearance of these early forms of life; but in tracing them and their successors upward through the succeeding ages, we may hope at least to reach some expressions of the laws of their succession, in possession of which we may return to attack the mystery of their origin.

First, it must strike every observer that there is a great sameness of plan throughout the whole history of marine invertebrate life. If we turn over the pages of an illustrated text-book of geology, or examine the cases or drawers of a collection of fossils, we shall find extending through every succeeding formation, representative forms of crustaceans, mollusks, corals, etc., in such a manner as to indicate that in each successive period there has been a reproduction of the same type with modifications; and if the series is not continuous, this appears to be due rather to abrupt physical changes; since sometimes where two formations pass into each other, we find a gradual change in the fossils by the dropping out and introduction of species one by one. Thus in the whole of the great Palæozoic Period, both in its Fauna and Flora, we have a continuity and similarity of a most marked character.

It is evident that there is presented to us in this similarity of the forms of successive faunas and floras, a phenomenon which deserves very careful sifting as to the question of identity or diversity of species. The data for its comprehension must be obtained by careful study of the series of closely allied forms occurring in successive formations, and our great and undisturbed Palæozoic areas in America, as Nicholson has recently pointed out, seem to give special facilities for this, which should be worked, not in the direction of constituting new species for every slightly divergent form, but in striving to group these forms into large specific types. The Rhynchonellæ of the type of *R. plena*, the Orthids of the type of *O. testudinaria*, the Strophomenæ of the types of *S. alternata* and *S. rhomboidalis*, the Atrypæ of the type of *A.*

reticularis, furnish cases in point among the Brachiopods. There is nothing to preclude the supposition that some of these groups are really specific types, with numerous race modifications. My own provisional conclusion, based on the study of Palæozoic plants, is that the general law will be found to be the existence of distinct specific types, independent of each other, but liable in geological time to a great many modifications, which have often been regarded as distinct species.

While this unity of successive faunæ at first sight presents an appearance of hereditary succession, it loses much of this character when we consider the number of new types introduced without apparent predecessors, the necessity that there should be similarity of type in successive faunæ on any hypothesis of a continuous plan; and above all, the fact that the recurrence of representative species or races in large proportion marks times of decadence rather than of expansion in the types to which they belong. To turn to another period, this is very manifest in that singular resemblance which obtains between the modern mammals of South America and Australia, and their immediate fossil predecessors—the phenomenon being here manifestly that of decadence of large and abundant species into a few depauperated representatives. This will be found to be a very general law, elevation being accompanied by the abrupt appearance of new types and decadence by the apparent continuation of old species, or modifications of them.

This resemblance with difference in successive faunas also connects itself very directly with the successive elevations and depressions of our continental plateaus in geological time. Every great Palæozoic limestone, for example, indicates a depression with succeeding elevation. On each elevation marine animals were driven back into the ocean, and on each depression swarmed in over the land, reinforced by new species, either then introduced or derived by migration from other localities. In like manner on every depression, land plants and animals were driven in upon insular areas, and on reëlevation again spread themselves widely. Now I think it will be found to be a law here that periods of expansion were eminently those of introduction of new specific types, and periods of contraction those of extinction, and also of continuance of old types under new varietal forms.

It must also be borne in mind that all the leading types of in-

vertebrate life were early introduced, that change within these was necessarily limited, and that elevation could take place mainly by the introduction of the vertebrate orders. So in plants, Cryptogams early attained their maximum as well as Gymnosperms, and elevation occurred in the introduction of Phænogams, and this not piecemeal, but as we shall see in the sequel, in great force at once.

Another allied fact is the simultaneous appearance of like types of life in one and the same geological period, over widely separated regions of the earth's surface. This strikes us especially in the comparatively simple and homogeneous life-dynasties of the Palæozoic, when for example we find the same types of Silurian Graptolites, Trilobites and Brachiopods appearing simultaneously in Australia, America and Europe. Perhaps in no department is it more impressive than in the introduction in the Devonian and Carboniferous Ages of that grand cryptogamous and gymnospermous flora which ranges from Brazil to Spitzbergen, and from Australia to Scotland, accompanied in all by the same groups of marine invertebrates. Such facts may depend either on that long life of specific types which gives them ample time to spread to all possible habitats, before their extinction, or on some general law whereby the conditions suitable to similar types of life emerge at one time in all parts of the world. Both causes may be influential, as the one does not exclude the other, and there is reason to believe that both are natural facts. Should it be ultimately proved that species allied and representative, but distinct in origin, come into being simultaneously everywhere, we shall arrive at one of the laws of creation, and one probably connected with the gradual change of the physical conditions of the world.

Another general truth, obvious from the facts which have been already collected, is the periodicity of introduction of species. They come in by bursts or flood-tides at particular points of time, while these great life-waves are followed and preceded by times of ebb in which little that is new is being produced. We labor in our investigation of this matter under the disadvantage that the modern period is evidently one of the times of pause in the creative work. Had our time been that of the early Tertiary or early Mesozoic, our views as to the question of origin of species might have been very different. It is a striking fact, and in illustration of this, that since the glacial age no new species of mammal can

be proved to have originated on our continents, while a great number of large and conspicuous forms have disappeared. It is possible that the proximate or secondary causes of the ebb and flow of life production may be in part at least physical, but other and more important efficient causes may be behind these. In any case these undulations in the history of life are in harmony with much that we see in other departments of nature.

It results from the above and the immediately preceding statement, that specific and generic types enter on the stage in great force and gradually taper off toward extinction. They should so appear in the geological diagrams made to illustrate the succession of life. This applies even to those forms of life which come in with fewest species and under the most humble guise. What a remarkable swarming, for example, there must have been of Marsupial Mammals in the early Mesozoic, and in the Coal formation the only known Pulmonates, four in number, belong to as many generic types.

I have already referred to the permanence of species in geological time. I may now place this in connection with the law of rapid origination and more or less continuous transmission of varietal forms. I may, perhaps, best bring this before you in connection with a group of species with which I am very familiar, that which came into our seas at the beginning of the Glacial age and still exists. With regard to their permanence, it can be affirmed that the shells now elevated in Wales to 1,200, and in Canada to 600 feet above the sea, and which lived before the last great revolution of our continents, a period vastly remote as compared with human history, differ in no tittle from their modern successors after thousands or tens of thousands of generations. It can also be affirmed that the more variable species appear under precisely the same varietal forms then as now, though these varieties have changed much in their local distribution. The real import of these statements, which might also be made with regard to other groups, well known to palæontologists, is of so great significance that it can be realized only after we have thought of the vast time and numerous changes through which these humble creatures have survived. I may call in evidence here a familiar New England animal, the common sand clam, *Mya arenaria*, and its relative *Mya truncata*, which now inhabit together all the northern seas; for the Pacific specimens, from Japan and

California, though differently named, are undoubtedly the same. *Mya truncata* appears in Europe in the Coralline Crag, and was followed by *M. arenaria* in the Red Crag. Both shells occur in the Pleistocene of America, and their several varietal forms had already developed themselves in the Crag, and remain the same today; so that these humble mollusks, littoral in their habits, and subjected to a great variety of conditions, have continued perhaps for one or two thousand centuries to construct their shells precisely as at present. Nor are there any indications of a transition between the two species. I might make similar statements with regard to the Astartes, Buccinums and Tellinæ of the drift, and could illustrate them by extensive series of specimens from my own collections.

Another curious illustration is that presented by the Tertiary and modern faunæ of some oceanic islands far separated from the continents. In Madeira and Porto Santo, for example, according to Lyell, we have fifty-six species of land shells in the former, and forty-two in the latter, only twelve being common to the two, though these islands are only thirty miles apart. Now in the Pliocene strata of Madeira and Porto Santo we find thirty-six species in the former, and thirty-five in the latter, of which only eight per cent. are extinct, and yet only eight are common to the two islands. Further there seem to be no transitional forms connecting the species, and of some of them the same varieties existed in the Pliocene as now. The main difference in time is the extinction of some species and the introduction of others without known connecting links, and the fact that some species, plentiful in the Pliocene, are rare now and vice versa. All these shells differ from those of modern Europe, but some of them are allied to Miocene species of that continent. Here we have a case of continued existence of the same forms, and in circumstances which the more we think of them the more do they defy all our existing theories as to specific origins.

Perhaps some of the most remarkable facts in connection with the permanence of varietal forms of species, are those furnished by that magnificent flora which burst in all its majesty on the American continent in the Cretaceous period, and still survives among us even in some of its specific types. I say survives; for we have but a remnant of its form living, and comparatively little that is new has probably been added since. The confusion which

obtains as to the age of this flora, and the discussions in which Newberry, Heer, Lesquereux and recently Mr. G. M. Dawson, have taken part, obviously arise, as the latter has I think conclusively shown, from the fact that this modern flora was in its earlier times contemporary with Cretaceous animals, and survived the gradual change from the animal life of the Cretaceous down to that of the Eocene and even of the Miocene. In a collection of these plants from what may be termed beds of transition from the Cretaceous to the Tertiary, I find among other modern species two recent ferns most curiously associated. One is the common *Onoclea sensibilis*, found now very widely over North America, and which in so-called Miocene times lived in Europe also. The other is *Davallia tenuifolia* of Eastern Asia—a fern not now even generically represented in North America, but still abundant on the other side of the Pacific. These little ferns are thus probably older than the Rocky Mountains and the Himalayas, and reach back to a time when the Mesozoic Dinosaurs were becoming extinct and the earliest Placental mammals being introduced. Shall we say that these ferns and along with them our two species of American Hazel and many other familiar plants, have propagated themselves unchanged for half a million of years?

Take from the western Mesozoic a contrasting yet illustrative fact. In the Jurassic or Cretaceous rocks of Queen Charlotte's Island, Mr. Richardson, of the Canadian Survey, finds Ammonites and allied cephalopods similar in many respects to those discovered further south by your California survey, and Mr. Whiteaves finds that some of them are apparently not distinct from species described by the Palæontologists of the Geological Survey of British India. On both sides of the Pacific these shells lie entombed in solid rock, and the Pacific rolls between as of yore. Yet these species, genera and even families, are all extinct—why, no man can tell, while land plants that must have come in while the survivors of these cephalopods still lived, reach down to the present. How mysterious is all this, and how strongly does it show the independence in some sense of merely physical agencies on the part of the manifestations of life.

Such facts as those to which I have referred, and many others which want of time prevents me from noticing, are in one respect eminently unsatisfactory, for they show us how difficult must be any attempts to explain the origin and succession of life. For

this reason they are quietly put aside or explained away in most of the current hypotheses on the subject. But we must as men of science face these difficulties, and be content to search for facts and laws even if they should prove fatal to preconceived views.

A group of new laws, however, here breaks upon us. (1) The great vitality and rapid extension and variation of new specific types. (2) The law of spontaneous decay and mortality of species in time. (3) The law of periodicity and of simultaneous appearance of many allied forms. (4) The abrupt entrance and slow decay of groups of species. (5) The extremely long duration of some species in time. (6) The grand march of new forms landwards, and upwards in rank. Such general truths deeply impress us at least with the conclusion that we are tracing, not a fortuitous succession, but the action of power working by law.

I have thus far said nothing of the bearing of the prevalent ideas of descent with modification, on this wonderful procession of life. None of these of course can be expected to take us back to the origin of living beings; but they also fail to explain why so vast numbers of highly organized species struggle into existence simultaneously in one age and disappear in another, why no continuous chain of succession in time can be found gradually blending species into each other, and why in the natural succession of things, degradation under the influence of external conditions and final extinction seem to be laws of organic existence. It is useless here to appeal to the imperfection of the record or to the movements or migrations of species. The record is now in many important parts too complete, and the simultaneousness of the entrance of the faunas and floras too certainly established, and moving species from place to place only evades the difficulty. The truth is that such hypotheses are at present premature, and that we require to have larger collections of facts. Independently of this, however, it appears to me that from a philosophical point of view it is extremely probable that all theories of evolution as at present applied to life, are fundamentally defective in being too partial in their character; and perhaps I cannot better group the remainder of the facts to which I wish to refer than by using them to illustrate this feature of most of our larger attempts at generalization on this subject.

First, then, these hypotheses are too partial, in their tendency to refer numerous and complex phenomena to one cause, or to a

few causes only, when all trustworthy analogy would indicate that they must result from many concurrent forces and determinations of force. We have all no doubt read those ingenious, not to say amusing, speculations in which some entomologists and botanists have indulged with reference to the mutual relations of flowers and haustellate insects. Geologically the facts oblige us to begin with Cryptogamous plants and mandibulate insects, and out of the desire of insects for non-existent honey, and the adaptations of plants to the requirements of non-existent suctorial apparatus, we have to evolve the marvellous complexity of floral form and coloring, and the exquisitely delicate apparatus of the mouths of haustellate insects. Now when it is borne in mind that this theory implies a mental confusion on our part precisely similar to that which in the department of mechanics actuates the seekers for perpetual motion, that we have not the smallest tittle of evidence that the changes required have actually occurred in any one case, and that the thousands of other structures and relations of the plant and the insect have to be worked out by a series of concurrent evolutions so complex and absolutely incalculable in the aggregate, that the cycles and epicycles of the Ptolemaic astronomy were child's play in comparison, we need not wonder that the common sense of mankind revolts against such fancies, and that we are accused of attempting to construct the universe by methods that would baffle Omnipotence itself, because they are simply absurd. In this aspect of them indeed such speculations are necessarily futile, because no mind can grasp all the complexities of even any one case, and it is useless to follow out an imaginary line of development which unexplained facts must contradict at every step. This is also no doubt the reason why all recent attempts at constructing "Phylogenies" are so changeable, and why no two experts can agree about almost any of them.

A second aspect in which such speculations are too partial, is in the unwarranted use which they make of analogy. It is not unusual to find such analogies as that between the embryonic development of the individual animal and the succession of animals in geological time placed on a level with that reasoning from analogy by which geologists apply modern causes to explain geological formations. No claim could be more unfounded. When the geologist studies ancient limestones built up of the remains of corals, and then applies the phenomena of modern coral reefs to explain

their origin, he brings the latter to bear on the former by an analogy which includes not merely the apparent results but the causes at work, and the conditions of their action, and it is on this that the validity of his comparison depends, in so far as it relates to similarity of mode of formation. But when we compare the development of an animal from an embryo cell with the progress of animals in time, though we have a curious analogy as to the steps of the process, the conditions and causes at work are known to be altogether dissimilar, and therefore we have no evidence whatever as to identity of cause, and our reasoning becomes at once the most transparent of fallacies. Farther we have no right here to overlook the fact that the conditions of the embryo are determined by those of a previous adult, and that no sooner does this hereditary potentiality produce a new adult animal, than the terrible external agencies of the physical world, in presence of which all life exists, begin to tell on the organism, and after a struggle of longer or shorter duration it succumbs to death and its substance returns into inorganic nature, a law from which even the longer life of the species does not seem to exempt it. All this is so plain and manifest that it is extraordinary that evolutionists will continue to use such partial and imperfect arguments. Another illustration may be taken from that application of the doctrine of natural selection to explain the introduction of species in geological time, which is so elaborately discussed by Sir C. Lyell in the last edition of his "Principles of Geology." The great geologist evidently leans strongly to the theory, and claims for it the "highest degree of probability," yet he perceives that there is a serious gap in it; since no modern fact has ever proved the origin of a new species by modification. Such a gap, if it existed in those grand analogies by which we explain geological formations through modern causes, would be admitted to be fatal.

A third illustration of the partial character of these hypotheses may be taken from the use made of the theory deduced from modern physical discoveries, that life must be merely a product of the continuous operation of physical laws. The assumption, for it is nothing more, that the phenomena of life are produced merely by some arrangement of physical forces, even if it be admitted to be true, gives only a partial explanation of the possible origin of life. It does not account for the fact that life as a force or combination of forces is set in antagonism to all other forces. It

does not account for the marvellous connection of life with organization. It does not account for the determination and arrangement of forces implied in life. A very simple illustration may make this plain. If the problem to be solved were the origin of the mariner's compass, one might assert that it is wholly a physical arrangement both as to matter and force. Another might assert that it involves mind and intelligence in addition. In some sense both would be right. The properties of magnetic force and of iron or steel are purely physical, and it might even be within the bounds of possibility that somewhere in the universe a mass of natural loadstone may have been so balanced as to swing in harmony with the earth's magnetism. Yet we would surely be regarded as very credulous if we could be induced to believe that the mariner's compass has originated in that way. This argument applies with a thousand fold greater force to the origin of life, which involves even in its simplest forms so many more adjustments of force and so much more complex machinery.

Fourthly, these hypotheses are partial, inasmuch as they fail to account for the vastly varied and correlated interdependencies of natural things and forces, and for the unity of plan which pervades the whole. These can be explained only by taking into the account another element from without. Even when it professes to admit the existence of a God, the evolutionist reasoning of our day contents itself altogether with the physical or visible universe, and leaves entirely out of sight the power of the unseen and spiritual, as if this were something with which science has nothing to do, but which belongs only to imagination or sentiment. So much has this been the case, that when recently a few physicists and naturalists have turned to this aspect of the case, they have seemed to be teaching new and startling truths, though only reviving some of the oldest and most permanent ideas of our race. From the dawn of human thought, it has been the conclusion alike of philosophers, theologians and the common sense of mankind, that the seen can be explained only by reference to the unseen, and that any merely physical theory of the world is necessarily partial. This, too, is the position of our sacred Scriptures, and is broadly stated in their opening verse, and indeed it lies alike at the basis of all true religion and all sound philosophy, for it must necessarily be that "the things that are seen are temporal, the things that are unseen, eternal." With reference to the primal

aggregation of energy in the visible universe, with reference to the introduction of life, with reference to the soul of man, with reference to the heavenly gifts of genius and prophecy, with reference to the introduction of the Saviour himself into the world, and with reference to the spiritual gifts and graces of God's people, all these spring not from sporadic acts of intervention, but from the continuous action of God and the unseen world, and this we must never forget is the true ideal of creation in Scripture and in sound theology. Only in such exceptional and little influential philosophies as that of Democritus, and in the speculations of a few men carried off their balance by the brilliant physical discoveries of our age, has this necessarily partial and imperfect view been adopted. Never indeed was its imperfection more clear than in the light of modern science.

Geology, by tracing back all present things to their origin, was the first science to establish on a basis of observed facts the necessity of a beginning and end of the world. But even physical science now teaches us that the visible universe is a vast machine for the dissipation of energy; that the processes going on in it must have had a beginning in time, and that all things tend to a final and helpless equilibrium. This necessity implies an unseen power, an invisible universe, in which the visible universe must have originated and to which its energy is ever returning. The hiatus between the seen and the unseen may be bridged over by the conceptions of atomic vortices of force, and by the universal and continuous ether; but whether or not, it has become clear that the conception of the unseen as existing has become necessary to our belief in the possible existence of the physical universe itself, even without taking life into the account.

It is in the domain of life, however, that this necessity becomes most apparent; and it is in the plant that we first clearly perceive a visible testimony to that unseen which is the counterpart of the seen. Life in the plant opposes the outward rush of force in our system, arrests a part of it on its way, fixes it as potential energy, and thus, forming a mere eddy, so to speak, in the process of dissipation of energy, it accumulates that on which animal life and man himself may subsist, and assert for a time supremacy over the seen and temporal on behalf of the unseen and eternal. I say, for a time, because life is, in the visible universe, as at present constituted, but a temporary exception, introduced from that un-

seen world where it is no longer the exception but the eternal rule. In a still higher sense then than that in which matter and force testify to a Creator, organization and life, whether in the plant, the animal or man, bear the same testimony, and exist as outposts put forth in the succession of ages from that higher heaven that surrounds the visible universe. In them, too, Almighty power is no doubt conditioned or limited by law, yet they bear more distinctly upon them the impress of their Maker, and, while all explanations of the physical universe which refuse to recognize its spiritual and unseen origin, must necessarily be partial and in the end incomprehensible, this destiny falls more quickly and surely on the attempt to account for life and its succession on merely materialistic principles.

Here, again, however I must remind you that creation, as maintained against such materialistic evolution, whether by theology, philosophy or Holy Scripture, is necessarily a continuous, nay, an eternal influence, not an intervention of disconnected acts. It is the true continuity which includes and binds together all other continuity.

It is here that natural science meets with theology, not as an antagonist, but as a friend and ally in its time of greatest need; and I must here record my belief that neither men of science nor theologians have a right to separate what God in Holy Scripture has joined together, or to build up a wall between nature and religion, and write upon it "no thoroughfare." The science that does this must be impotent to explain nature and without hold on the higher sentiments of man. The theology that does this must sink into mere superstition.

In conclusion, can we formulate a few of the general laws, or perhaps I had better call them the general conclusions respecting life, in which all Palæontologists may agree. Perhaps it is not possible to do this at present satisfactorily, but the attempt may do no harm. We may, then, I think, make the following affirmations:—

1. The existence of life and organization on the earth is not eternal, or even coeval with the beginning of the physical universe, but may possibly date from Laurentian or immediately pre-Laurentian times.

2. The introduction of new species of animals and plants has been a continuous process, not necessarily in the sense of deriva-

tion of one species from another, but in the higher sense of the continued operation of the cause or causes which introduced life at first. This, as already stated, I take to be the true theological or Scriptural as well as scientific idea of what we ordinarily and somewhat loosely term creation.

3. Though thus continuous, the process has not been uniform; but periods of rapid production of species have alternated with others in which many disappeared and few were introduced. This may have been an effect of physical cycles reacting on the progress of life.

4. Species like individuals have greater energy and vitality in their younger stages, and rapidly assume all their varietal forms, and extend themselves as widely as external circumstances will permit. Like individuals also, they have their periods of old age and decay, though the life of some species has been of enormous duration in comparison with that of others; the difference appearing to be connected with degrees of adaptation to different conditions of life.

5. Many allied species, constituting groups of animals and plants, have made their appearance at once in various parts of the earth, and these groups have obeyed the same laws with the individual and the species in culminating rapidly, and then slowly diminishing, though a large group once introduced has rarely disappeared altogether.

6. Groups of species, as genera and orders, do not usually begin with their highest or lowest forms, but with intermediate and generalized types, and they show a capacity for both elevation and degradation in their subsequent history.

7. The history of life presents a progress from the lower to the higher, and from the simpler to the more complex, and from the more generalized to the more specialized. In this progress new types are introduced and take the place of the older ones, which sink to a relatively subordinate place and become thus degraded. But the physical and organic changes have been so correlated and adjusted that life has not only always maintained its existence, but has been enabled to assume more complex forms, and that older forms have been made to prepare the way for newer, so that there has been on the whole a steady elevation culminating in man himself. Elevation and specialization have, however, been secured at the expense of vital energy and range of adaptation,

until the new element of a rational and inventive nature was introduced in the case of man.

9. In regard to the larger and more distinct types, we cannot find evidence that they have, in their introduction, been preceded by similar forms connecting them with previous groups; but there is reason to believe that many supposed representative species in successive formations are really only races or varieties.

10. In so far as we can trace their history, specific types are permanent in their characters from their introduction to their extinction, and their earlier varietal forms are similar to their later ones.

11. Palæontology furnishes no direct evidence, perhaps never can furnish any, as to the actual transformation of one species into another, or as to the actual circumstances of creation of a species, but the drift of its testimony is to show that species come in *per saltum*, rather than by any slow and gradual process.

12. The origin and history of life cannot, any more than the origin and determination of matter and force, be explained on purely material grounds, but involve the consideration of power referable to the unseen and spiritual world.

Different minds may state these principles in different ways, but I believe that in so far as palæontology is concerned, in substance they must hold good, at least as steps to higher truths. And now allow me to say that we should be thankful that it is given to us to deal with so great questions, and that in doing so, deep humility, earnest seeking for truth, patient collection of all facts, self-denying abstinence from hasty generalizations, forbearance and generous estimation with regard to our fellow-laborers, and reliance on that divine Spirit which has breathed into us our intelligent life, and is the source of all true wisdom, are the qualities which best become us. While thanking you for the honor which you have done me in inviting me to deliver this address, and in conveying to you the kindly regards and good wishes of all your fellow-workers in the Canadian Dominion, allow me to express the fervent hope that we all may be one in our patient and earnest search for the truth.

PAPERS READ.

Rectification of the Geological Map of Michigan. By Alexander Winchell, of Syracuse, N. Y.

The determination of the detailed geology of the Lower Peninsula of Michigan, is a work of extreme difficulty. It is a work which will probably never be accomplished, though the excavations which usually accompany the progress of settlement and civilization, will gradually add to the stock of data, and result in a slow approximation toward a complete solution of the geological problem. Most of the Peninsula is buried beneath a heavy mantle of drift. Only small portions of its shores exhibit the usual number of rock-exposures. These are found along the south shore of Little Traverse Bay, and extending into the mouth of Grand Traverse Bay; along a portion of the borders of Huron County, east and west of Point aux Barques; along the borders of Alpena and Presque Isle Counties on Lake Huron, and along the western extremity of Lake Erie. The only districts in the interior which furnish anything like adequate outcrops, are in the counties of Alpena, Alcona, Emmet, Charlevoix, Leelanaw, Kent, Calhoun, Branch, Hillsdale, Lenawee, Monroe, Jackson, Eaton, Genesee, Sanilac, Huron, Tuscola and Iosco.

On the contrary, the shore of Lake Michigan exhibits no outcrop of strata older than the drift, along the whole eastern border from New Buffalo to Grand Traverse Bay, and from Little Traverse Bay to Mackinac. There is no rock in place from Thunder Bay to and around Saginaw Bay to Point aux Barques, save at Alabaster and Point au Grès; nor is there an outcrop from Huron County to the mouth of the Detroit River. In the interior no outcrop exists along the Grand Rapids and Indiana Railroad between Kent County and Little Traverse Bay. None exists along the Flint and Père Marquette Road from Saginaw City to Ludington; none on the Detroit and Bay City Road; none on the Grand Trunk Road; none on t e Detroit and Milwaukie, between Detro t and Corunna; none on the Jackson, Lansing and Saginaw Road, save

at Owasso, between Jackson and the Straits of Mackinac. Similar statements are true of most of the railroads of the Peninsula. There is no other state east of the Mississippi, whose geological study has been so little aided by railway excavations. In the whole Peninsula there are thirty counties in which no exposure of stratified rocks is to be found. There are fifteen counties affording feeble exposures and twenty counties containing good exposures, though in eight of them the outcrops are limited to a single spot.

The following is a list of the counties:

Without any outcrop whatever:—Berrien,[1] Cass, Allegan,[1] Oakland, Macomb, Lapeer, Gratiot, Montcalm, Newaygo, Mecosta, Isabella, Midland, Gladwin,[2] Clare, Osceola, Lake, Mason, Manistee, Wexford, Missaukee, Roscommon,[2] Ogemaw, Crawford, Kalkaska, Benzie, Otsego, Montmorency, Emmet.

With very obscure outcrops:—St. Joseph, Branch, Van Buren, Kalamazoo, Barry, Ingham, Livingston, Clinton, Sanilac, Tuscola, Saginaw, Oceana, Grand Traverse, Antrim, Cheboygan.

With good or fair outcrops:—Hillsdale, Lenawee, Monroe, Calhoun, Jackson, Washtenaw, Wayne, Eaton, Ottawa, Kent, Ionia, Shiawassee, Genesee, Huron, Iosco, Alcona, Leelanaw, Charlevoix, Alpena, Presque Isle.

In the western and central portion of the Peninsula, bounded west by Lake Michigan, south by the Detroit and Milwaukie Railway, east by the meridian of East Saginaw, and north by the line stretching from Grand Traverse Bay to Thunder Bay, there is not a single outcrop known, save certain indications in Oceana County to which I shall proceed to refer. The whole extent of this completely rockless area is not less than 17,000 square miles, and covers half the area of the Lower Peninsula.

[1] At various points in Berrien, Allegan and Van Buren counties the superficial materials are cemented on an extensive scale, presenting the appearance of ledges of sandstone and conglomerate; and in all parts of the state beds of travertin are often mistaken for limestones in place.

[2] Ira W. La Munyon has giv n me localities of outcrops as follows:—*Gladwin County*, from centre of T. 17 N., 1 W., to section 18, T. 18 N., 1 E., sandstone; section 23, T. 19 N., 1 W, limestone; sections 8 and 17, T. 20 N., 1 W., and sections 13 and 14, T. 20 N., 2 W., also 20 N., 3 W., beds of Michigan Salt Group. *Roscommon County*, T. 21 N., 1 W., strata of Michigan Salt Group. He says the outcrops cont'nue in the small streams, well up to the head of Sugar Creek, a branch of the Tittabawassee. He estimates its thickness at 202 feet. Mr. La Munyon's au ority is weakened by his statement on another occasion, that an outcrop a mile long occurs in the southwestern part of Osceola County, near the Muskegon River. I have been through the region without finding any trace of an outcrop.

The bed of drift, as will be inferred, attains generally, a very considerable thickness. This is illustrated by the following table of localities well distributed over the Peninsula.

LOCALITY.		FEET.
Ann Arbor, Main st.,		164
Detroit,		130
Wyandotte, Wayne Co.,		75
Toledo, Ohio,		115
Ida, Monroe Co.,		50
Hudson, Lenawee Co.,		60
Jackson, two miles S. of the city,		80
Newport (Marine City), St. Clair Co.,		188
Hadley, Lapeer Co.,		200
Mason, Ingham Co.,		45
Lansing, Lansing House,		55
Lansing, State Industrial School, fifty feet higher than the city,		101
Laingsburgh, Shiawassee Co., forty-three feet below Lansing,		91
Bennington, Shiawassee Co.,		47
St. John's, Clinton Co.,	over	200
Grand Haven, Ottawa Co.,	over	195
East Saginaw,		92
Bay City,		86
Portsmouth, Bay Co.,	107 to	125
St. Louis, Gratiot Co.,		192
Muskegon		220
Greenville, Montcalm Co.,	over	70
Manistee,	over	101
Hart, Oceana Co. (six miles South of), a well		160
Provemont, Leelanaw Co.,		310
South shore of Little Traverse Bay	To level of Lake Michigan	200
Clay Banks, Oceana Co.,		275
Sleeping Bear, Benzie Co.,		300
Sliding Bank, Presque Isle Co.,		77

In numberless localities, the hills of drift material are seen rising 100, 200 and 300 feet above the intervening valleys. Examples may be seen in Leelanaw and Washtenaw counties. Most of the larger streams have formed cuts exposing cliffs of unconsolidated materials from 100 to 400 feet. This is especially the

case with the Sable (T. 26 N., 5 E.; 25 N., 5 E.; 24 N., 5 E.; 24 N., 6 E.;), the Manistee (T. 24 N., 9 W.; 22 N., 13 W.; 22 N., 15 W.), and the Muskegon.

In constitution, these beds of superficial materials are predominantly sandy above and argillaceous below, with a very constant bed of sand or pebbles at bottom. Over considerable areas the more arenaceous portions are absent; while in other districts they attain a depth of sixty, eighty or more feet, without much admixture of clay; though frequently thin sheets of clay are found irregularly disposed. Few northern boulders are disseminated through the sands, while they are generally abundant in the underlying clays. The higher portion of the clays, however, contains the largest number of boulders. These upper boulder clays are unstratified. The materials are spread out in irregular sheets conformable to the underlying surface, like a bed of lava poured over a surface of schists. Below these we find, somewhat generally, a deposit of fine, horizontally stratified clays containing only well-worn northern pebbles, up to half an inch in diameter, and quite frequently, almost wholly destitute of all pebbles. This evenly and horizontally stratified condition of the lower argillaceous drift materials, is most conspicuously noticed along the lake shores, as at the Claybanks in Oceana County, and at Sleeping Bear, in Benzie County. It is a mistake, however, to suppose them restricted to these situations; as I have observed them generally throughout the interior of the Peninsula, wherever excavations have reached the lower sheets of the formation. I would cite a fine bed of this kind at Reed City, 420 feet above Lake Michigan, and another at Evart, in Osceola County; a similar one at Hart and eastward from there in Oceana County, and other examples in section 3, T. 22 N., 13 W. on the Manistee River, and thence to the mouth of the Pine River, and up the Pine. In a well bored at Provemont, in Leelanaw County, the stratified clay was 135 feet thick. At Ann Arbor it was thirty-three feet. This clay, however, is not everywhere present. The rocky strata when near the surface are sometimes covered only by the unstratified clays, or by these and the superficial sands. Even when deeply buried, the unstratified, boulder-bearing clays seem sometimes, as at Ann Arbor, to attain a thickness of fifty to eighty feet. The upper clays, and often some beds of the lower, afford bricks of a red color; but the finely stratified clays afford, very commonly, the light colored bricks so well known as "Milwaukie bricks." These are of

a very pale lemon color. In many situations, however, the clays of which I speak produce a brick almost white. I would cite the bricks manufactured at and near Fruitport, Muskegon County, and at Reed City, Osceola County.

The constancy and thickness of the bottom bed of sand and pebbles will be illustrated by the following fifteen examples of artesian borings in different parts of the state and its borders.

At depth of ft.	Thickness, ft.	
		Hudson, Lenawee Co.
0	50	Clay.
50	5	COARSE GRAVEL.
55	5	SAND.
60	13	Blue clay, boulders.
73		GRAVEL.
		Ida, Monroe Co.
0	46	Hard clay.
46	4	COARSE GRAVEL.
50		Limestone.
		Lansing (Lansing House).
0	4	Sand.
4	10	Light blue clay.
14	4	Sand and clay.
18	37	SAND AND GRAVEL.
55	7	Sandrock.
		Lansing (Industrial School).
0	36	Clay and gravel.
36	5	Sand and gravel.
41	4	Sandy hard pan.
45	39	"Lake sand" and gravel.
84	16	CLAY, SAND AND GRAVEL.
100	1	"LAKE SAND" & GRAVEL.
101	154	Sandrock.
		Bennington, Shiawassee Co.
0	20	Sand.
20	10	White clay.
30	10	Blue clay.
40	7	Clay and gravel.
47	5	PEBBLES AND FRAGMENTS.
52	10	Soft sandrock.
		Laingsburg, Shiawassee Co.
0	45	Clay.
45	46	GRAVEL.
91	15	Limestone.
		Mason, Ingham Co.
0	7	Sand and gravel.
7	13	Brick clay.
20	4	Red clay and boulders.
24	21	Blue clay.
45		Sandrock.
		Grand Rapids (State Salt Well).
0	2?	Alluvial.
	6	Clay.
32		GRAVEL AND SAND.
40		Clay, gypsum, etc.
		Spring Lake, Ottawa Co.
0	13	Sand.
13	30	Blue clay.
43	5	Sandy hardpan.

At depth of ft.	Thickness, ft.	
		Spring Lake, Ottawa Co.
48	48	Blue clay.
96	20	Brown clay.
116	52	Blue clay.
168	12	GRAVEL, WATER.
180	20	Sandrock.
		Muskegon.
0	50	Sand.
50	3	Clay.
53	10	Clay and sand.
63	147	Clay [stratified].
210	10	GRAVEL AND BOULDERS.
220	68	Sandstone.
		Manistee.
0	7	Clay.
7	23	White sand.
30	4in.	Hardpan.
30	12	Gravel, sand and clay.
42	18	Sand and gravel.
60	37	GRAVEL AND SAND.
97	4	GRAVEL. WATER.
101		Rock not positively reached.
		St Louis, Gratiot Co.
0	40	Clay, gravel and boulders.
40	30	Blue clay.
70	13	"Fire clay."
83	39	Sand and gravel.
122	15	Bluish, indurated, shaly clay.
137	55	SAND AND GRAVEL.
192	8	PEBBLES, water.
200		Rock not positively reached.
		Provemont, Leelanaw Co.
0	146	Sand, gravel and boulders.
146	135	Pure clay.
281	25	Clay and sand.
306	1	BOULDERS.
307	5	ARTESIAN WATER, oil, bituminous matters.
312		Limestone.
		Holland, Northern Ohio.
0	98	Clay.
98	2	COARSE GRAVEL.
100		Slate rock.
		Bryan, Northern Ohio.
0	40	Blue clay.
40	6	Hard boulders.
46	35½	Hard boulder clay.
81½	5	"Gray rock."
86½	15	"Slate rock."
101½	½	"White flint."
102	5	COARSE SAND.
107		Solid rock.

Of the boulders disseminated through the Drift deposits, by far the larger proportion—probably nineteen-twentieths—are derived from the silicious, granitic and dioritic rocks, beyond the limits of the Peninsula. In addition to these, boulders of limestone are generally distributed on the surface of the Peninsula—nearly restricted, however, to the upper portions of the Drift. The hard, subcrystalline, Niagara limestone, from the north shores of Lakes Huron and Michigan are scattered, in seemingly undiminished abundance, quite to the Ohio line. I saw recently, in the town of Shelby, Oceana County, a tabular mass of Niagara limestone 10 feet long and 5 feet wide, containing many characteristic fossils, including *Halysites* and *Pentamerus*. The Hamilton limestones of Little Traverse and Thunder Bays, and the intervening region, have supplied a still larger proportion of calcareous boulders. The finest fossils which I have seen from both these formations have been weathered out in the Drift. The Hamilton fragments are generally rounded, more rounded than the Niagara; but this is clearly the result of easier solution in the soil, and not of attrition, as in the case of the silicious boulders, which still bear scratches and marks of numberless collisions. A third class of calcareous boulders has been afforded by the Carboniferous limestone. This is a comparatively feeble formation, however, and is scarcely represented in the general distribution, save by silicified masses of *Lithostrotion*.

The general constitution of this heavy sheet of drift is of northern and extra-peninsular materials, modified by proximity of local rock formations. The local contributions, where the rock lies near the surface, constitute a large percentage. In reference to their condition, I think I am authorized in a generalization of some importance. The local contributions, at the same time that they do not bear evidence of rolling and extensive transportation, seem to have been moved by a much gentler agency than that which bore the great bulk of the Drift. It looks like a work superimposed upon the older and more energetic one. The local fragments are most noticeable in the upper, more arenaceous and confusedly stratified portions. They are either simply weathered or more or less angular. Such fragments may be traced, continually increasing in numbers, to the vicinity of the bed rock. Here we see the rock itself passing from its characteristic, consolidated condition, to a shattered and dislocated state, with the fragments

more and more loosened and separated, until it blends with a mere stream of receding, diluvial débris. This disposition of the local materials is especially noticeable in deposits derived from the Hamilton and Carboniferous limestones, from the black Genesee shale and from the shales and coal seams of the Coal Measures. This, indeed, is not a singular phenomenon, as it has been remarked by others; and I have myself seen the process of atmospheric disintegration, dislocation and dissemination of products, fine or coarse, very extensively exemplified in the Cretaceous and Eocene limestones of the Southern States; and I believe it is the same series of changes, carried forward under atmospheric and modern influences, which, in Brazil and other tropical and subtropical regions, have been sometimes referred to those glacial or other energetic agencies, which we find illustrated on so grand a scale in the more constant features of our Northern Drift.

The precise induction which I wish to draw out from these phenomena in Michigan, is the differentiation of the older and newer transportive agencies. The older was powerful, sweeping, pervasive; the newer was gentle and local in its action. The older bore its burdens from beyond the lakes; the latter strewed the fragments, sands and dust of the local rocks, along a stream of a few rods or miles. The older agency was unique, exceptional; the newer was evidently atmospheric and aqueous, and blends in its results with those of recent agencies.

These phenomena of aqueous and later action I do not confound with those which have been produced, within definite limits, by a higher stage of the water of the Great Lakes. These are still more recent. They have obliterated the original features of the surface, within certain limits of elevation above the lake-levels, and have rearranged the upper portions of the Drift, strictly according to the method of aqueous sedimentation. This work of the lakes is modern — perhaps even more recent than the advent of man.

I have made these observations upon the Drift only incidentally. I desired to impress upon the attention of the Section the voluminous character of the deposits which envelope the Lower Peninsula, and to embrace the opportunity to drop a note on their constitution and distribution. Little has been published about the geology of this Peninsula. Having said what I have, it will be apparent that good reasons have existed for the slowness with which the

geology of the Peninsula has been brought to the notice of the world; and for the somewhat hypothetical and varying character of some of the generalizations which have been put forth. My own connection with these developments justifies me and stimulates me in making every contribution possible toward an accurate geological map. I have made three successive attempts to delineate, on a published map, the knowledge which had been attained in reference to the rocky structure of the Peninsula. The first was in 1865, the second, in 1866, and the third, in 1873. For the reasons already indicated, all such maps must be regarded as merely tentative and provisional. Some knowledge of our geology was well settled; some data were still under discussion; and for the rest of our territory, only shrewd scientific guesses remained. These, however, received only as the best guesses which could be made, have been much better for the public and for science, than profound ignorance or erratic surmisings.

Especially has that vast territory constituting the central and western portions of the Peninsula, so completely buried in drift, been the domain of shrewd guesswork. Between the fixed points of our geology, we have drawn the lines according to our best judgment. This, indeed, is all that can be done in any case; but here the islands of rock are peculiarly remote, and the navigation between them correspondingly perilous. Accordingly it will be found that in the western part of the Peninsula, the lines upon my map of 1865 are located several miles further west than on my map of 1873. This results partly from conflicting testimonies, and partly from a difference in the interpretations put upon such indications as come within reach. I shall show that the older map is most accurate.

In all the western and southwestern parts of the Peninsula, the Carboniferous limestone is almost the only formation which affords us positive criteria. Beginning near Leoni in Jackson County, we trace it through numerous feeble outcrops, along a very narrow belt, through the centre and western part of that county, and lose it again until we reach Bellevue in Eaton County. Here is one of its most satisfactory exposures. In passing Barry County, it remains concealed. The next report of it is in the southeastern portion of Kent County, in the township of Bowne. Thence we trace it, by frequent outcrops, through Gaines and Paris, to Grand Rapids. Here it is extensively exposed in low outcrops, and is

worked largely, especially in the bed of the river, as a quarry stone. In Kent County, the belt of outcrop widens to fifteen miles. We find exposures north of Grand Rapids in the townships of Algoma, Courtland and Nelson. It is next reported to appear in Cazenovia, the eastern town of Muskegon County. It should pass under the northeastern corner of Ottawa, and the southwestern corner of Newaygo. Possibly the "rapids" at Newaygo are determined by the formation. The first actual outcrop, however, is in the town of Dayton, in the western part of Newaygo County.

Here, the formation, until recently, has been lost. In Oceana County, however, traditions of limestone outcrops have existed, ever since the period of the land-surveys. The elder Farmer, in his map of the State — to this day unequalled for accuracy and detail — recorded limestone ledges in two townships of that county. Accordingly, in my map of 1865 — published without opportunity for personal examination, as the official survey of the State was only continued two years — I extended the Carboniferous limestone westward into Oceana County. Subsequently, however, in 1869, Mr. A. S. Wadsworth, an assistant on the new survey, reported the alleged outcrops to be nothing more than detached fragments in the soil. This report convicted Farmer's map of error, but I have since learned that in another case, in the southeastern part of Wexford County, a ledge recorded upon the map, and one which had given its name to "Stone Ledge Lake," is nothing more than a mass of metamorphic boulders. It may be remarked that such a mass of boulders is often designated "a ledge" by the common people, as I have practically learned within a few weeks in researches upon the southern shore of Big Clam Lake, in Wexford County. In my map, therefore, of 1873, relying on Mr. Wadsworth's determinations, and on the configuration of the shore of Lake Michigan, I carried the belt of limestone along a region much farther east than in my former maps. The location of one formation, in a region destitute of outcrops, would affect the positions of those on either hand. The consequence is, that in my last map, all the formations are too little extended westward, as I shall show.

Having had occasion recently to resume the study of the western portion of the State, I have visited every reported outcrop in Oceana County. In the town of Ferry (Sections 7, 13 and 14, T.

14, N. 16, W.), southeast of the county centre, we find exposures of limestone up to 400 square yards in extent, some of which have been extensively quarried for lime. It is difficult to believe that such masses have been detached from their original bed, especially as we have not explored beneath them. Nevertheless, I hesitate to pronounce them genuine outcrops. Their dip is sometimes with the slope of the hillside on which they appear. In some cases they have been worked out; and, finally, we find extensive tabular masses of limestone similarly situated, in numerous localities in the southern part of Jackson and northern part of Lenawee County, which are demonstrably out of place, since they squarely overlie the region of the Marshall sandstone. It may be added that an equally curious circumstance in these cases is the evidence from fossils, that these masses have undergone a *northward transportation* from the region of the Hamilton and Corniferous outcrops, in northern Ohio and Indiana.

In the town of Shelby (Sections 16, 17 and 20, T. 14, N. 17, W), Oceana County, are numerous further exposures. One of these is a mass originally twenty feet long and fifteen feet broad, and projecting four feet above the surface. It has supplied material for several lime-kilns. It slopes northwest, down the hill, however, at an angle of 30°. Some minor exposures present a more fixed and convincing attitude. Singularly, in the same vicinity, lies a mass of Niagara limestone, ten feet long, and four or five broad and of unknown thickness. A large slab for a hearth has been removed from the upper side. Its geological age is manifest from the presence of *Halysites* among the fossils. The Niagara limestone of Michigan, moreover, presents easily identifiable characters.

In the town of Hart (Section 14, T. 15, N. 17, W), next north of Ferry, occur numerous localities where the stream of limestone fragments indicates the proximity of the formation; and some larger masses have been quarried and present the usual appearance of genuine outcrops.

In Elbridge (Sections 3, 9, 16 and 18, T. 15, N. 16, W) similar phenomena occur; and these are again repeated in the town of Crystal (Sections 16, 20 and 34, T. 16, N. 16, W), on the northern border of the county; and again in the town of Weare (Sections 23, 28 and 32, T. 16, N. 17, W.). In the northern part of Section 28, Weare, in one place the rock presents a rugged

protruding mass, having every aspect of a genuine, though inconspicuous outcrop near the summit of a hill. This also has been quarried.

Furthermore in travelling from Ludington to Pentwater, one sees the fields at the distance of four to six miles from the former place, in Mason County, abounding to an unusual extent in fragments of the same formation.

Nor is this all. In the southwest corner of Oceana County, in the town of Claybanks (Section 21, T. 13, N. 18, W.), and within half a mile of the shore of Lake Michigan, are numerous occurrences of similar limestone masses, which few would hesitate to pronounce the formation in place. Here, as elsewhere, the deposits have been quarried, with every indication of an exhaustless supply of the rock. Masses of limestone as solid as an ordinary ledge, and from four to ten feet square, at least, have been struck in more than half a dozen places in cultivating a contiguous field. The lake-bluff here, called "the claybanks," is 275 feet high; and the general surface, for some miles around, must average about 200 feet above the lake level. The section exposed at the claybanks is as follows:

	FEET.
E. Evenly stratified sand and sandy clay, .	80
D. Pebbly clay intimately mixed with much sand. Color pale pink-tinted, . . .	35
C. Sand mixed with clay, horizontally stratified, having a bed of pebbles and boulders at bottom, from which issue numerous copious springs, ...	65
B. Compact, tough, slightly tinted boulder clay, mostly concealed by débris. Stratification obscure as far as observed, .	10
A. Talus of sand to the water's edge, . . .	10
Total, ...	200

This depth of unconsolidated materials is within less than half a mile of the limestone outcrops last mentioned.

Along the beach lie innumerable water-worn pebbles of the Hamilton and Niagara limestones. Amongst them are many fragments of the Carboniferous limestone — not water-worn, but more or less angular, and seeming to have fallen down from above.

The dimensions of the latter class of fragments are often considerable. I measured one seven feet by ten, and over three feet in thickness. Another huge block towers up, resting on its edge. It is an imperfectly stratified mass five feet thick, fourteen feet long and standing ten feet high, containing 700 cubic feet of stone. One of the vertical faces is smoothed and marked with three sets of striæ running in the relative directions of the three sides of an equilateral triangle.

In reference to the limestone exposures examined in Oceana County, three general observations may be made.

1. The rock is the Carboniferous limestone. Not a single identifiable fossil has been observed, save a specimen of *Allorisma*, which, after all, is a species not hitherto known in Michigan, if described at all. Nevertheless, the rock presents that peculiar curdled and imperfectly stratified structure, resulting in the gnarled and rugged weathered surfaces with which we become familiar in Kent and Jackson counties. There is a second variety of the rock more evenly stratified and resembling the Grand Rapids outcrop; but the characteristic greenish stains reveal its identity with the Carboniferous limestone of Jackson County. Moreover, the peculiar dislocated and faulted arrangement of the fibres of the lignilitic structure is something characteristic. Finally, no other limestone in or about the borders of the State is so completely destitute of recognizable organic forms. Were these exposures of the Hamilton, Corniferous or Niagara limestone, the ever present fossils would tell the tale of its age in nine instances out of ten.

2. If none of these masses of rocks prove to be actually in place, they nevertheless seem to locate quite approximately the place of the formation from which they are derived. Restricted to a definite belt, occurring in such numbers and in masses of such magnitude as they do, and along the trend of the formation determined by a line of outcrops from Jackson County to Kent and Newaygo, there can now be but little guesswork in stretching the blue of the Carboniferous limestone in quite a broad belt, from Grand Rapids to Pentwater.

3. But if these enormous sheets of limestone are all, as some of them undoubtedly are, mere loose masses floating in a bed of sand one or two hundred feet above the solid rock, the fact is one of considerable geological significance. The agency which moved

them was, demonstrably, not that general one which transported fragments scores and hundreds of miles, and deposited them in a worn and battered condition — that is, it was something different from the general drift agency — it was not a moving glacier. Further, the translation of the rock masses must have been simultaneous with the movement of the sands which envelope them. The semi-stratified condition of the sands suggests the disposing action of water; but water alone could not have transported these rock-masses, unless it acted with such violence as must have swept the sands from the face of the Peninsula. Moving water assorts; here we have added to the assorted sands a belt of rocky slabs of such magnitude as to constitute a glaring antithesis to assortment. What must have been the nature of the agency which acted like water in assorting, and quite unlike water in mixing?

I feel compelled to resort to a theory which facts forced upon my attention years ago.[3] It seems to me that upon the surface of the water whose movements assorted the sands, fields of ice were floating, capable of transporting huge blocks of limestone. The shallow portions of the water — the evidence is that all portions were comparatively shallow — congealed to a considerable depth, would embrace in ice the protruding portions of many rocky ledges. On occasion, then, of a rise in the level of the water, large masses of rock might have been lifted from their resting places and floated away. It will at once be understood how such action would result in the phenomena which we witness. To such agency I am inclined to attribute the northward translation of the tables of Hamilton and Corniferous limestone, which rest in the sands overlying Carboniferous rocks, in Jackson and Lenawee counties. This subject I discussed in 1865, and I content myself with contributing these additional facts.

Having traced the Carboniferous limestone to the vicinity of Pentwater, it would be desirable to trace it beyond, but I am convinced the data for doing this with accuracy are not accessible to the geologist. To the north of this, we have the whole system of older formations, exhibiting conformable trends from southwest to northeast. The Hamilton limestones stretch from Leelanaw County through Charlevoix and Emmet. Their territory is definitely mapped. Next to the south, is the narrow belt of the Black

[3] Some indications of a Northward Transportation of Drift Materials in the Lower Peninsula of Michigan. *Amer. Jour. Sci. and Arts*, Vol. X, Nov., 1865.

or Genesee Shale, whose position is fixed by outcrops in Benzie, Leelanaw, Antrim, Charlevoix and Emmet counties. There is no guesswork here. The trend is northeast and southwest, with a slight curvature. Next to this, and further toward the south, should appear the broad belt of the Huron Shales—the Portage and Chemung of New York. Unfortunately, however, these shales make their appearance at the surface, at only four localities. One of these is at Tucker's Point on the west side of the Peninsula of Grand Traverse Bay; another is at the point of the Peninsula, and the two others are at Brownstown and Eastport, two miles apart, on the east shore of the Bay. These outcrops determine a strike for the formation, which, as far as it goes, is quite parallel with the other trends.

Between the Huron group and the Carboniferous limestone, lie the Marshall Group and the Michigan Salt Group. These can have no other strike than northeast; and the Carboniferous limestone must follow them, starting from the vicinity of Pentwater. But no outcrops exist in that direction. I find an old memorandum of a reported outcrop near Muskrat Lake, in Missaukee County,[4] but I failed to hear of it in my recent explorations; and still later inquiries fail to confirm the account. I can only affirm that the locality is where outcrops should be expected.

In the absence of well defined outcrops, there are several classes of indications to which the geologist may resort. These are: 1. The results of artesian borings. 2. The character of the local drift, including the soil. 3. The topography. 4. The timber. 5. The direction of the streams, which generally tends to conform either to the dip or the strike of the rocks.[5] Artesian borings reveal the presence of a sandstone underneath Spring Lake, Ottawa County, and again at Muskegon, where it has a thickness of sixty-eight feet. This is, beyond all question, the Marshall Sandstone, which we detect in a number of outcrops in the eastern part of Ottawa County and the western part of Kent, and again in the southern part of Ottawa County, giving a breadth of at least twenty-one miles to the formation. The Marshall Group must therefore terminate on the lake shore, in the vicinity of Little Point Sable; and the Michigan Salt Group, must reach the shore

[4] This memorandum was furnished in 1861, by Edward F. French, then of Greenville, Montcalm County, now deceased.

[5] This criterion is only asserted to apply in a region comparatively undisturbed, like the Lower Peninsula of Michigan.

between that point and Pentwater. The interrupted circuit of the Marshall Group must be resumed in the neighborhood of Grand Point Sable, and that of the Michigan Salt group, in the vicinity of Lincoln, in Mason County.

If we appeal to the characters of the soil and local drift to guide us, we find some reason for suspecting that the broad, sandy, comparatively level belt stretching diagonally through the counties of Manistee, Wexford, Missaukee and Kalcaska, into Crawford, is the place, in a general way, of the Marshall Group. Similarly, the Michigan Salt Group has its surface characteristics. Its presence is attended by a soil less arenaceous, with a corresponding thickening of the argillaceous deposits. A region of this character actually follows the arenaceous belt just traced. A series of salt springs furnishes accessory indications.

If we apply the criterion of topography we make still further progress. The region of the Michigan Salt Group is characterized by abrupt declivities underlaid by beds of clay and shale. Some of these are the slopes of elongated ridges which rise abruptly above the general level on one side and slope off gently on the other, or direction of the dip. Some are the funnel-like slopes of a sink-hole, caused, as I presume, by the local dissolution of a thick underlying bed of gypsum, through the action of running water. The gypsum of Michigan, it will be remembered, is a persistent stratum from twelve to twenty feet thick. The sink-holes which mark its local removal, become at once the sign of the presence of the formation and of the gypseous deposit. These sink-holes may be dry, or may form small lakes with steep, clayey banks. Now in Mason County, in T. 17, N. 16, W., is a multitude of sink-holes, and this region is immediately contiguous to the supposed prolongation of the Carboniferous Limestone. Northeast of this, in T. 18, N. 15, W., we find deep precipitous gorges extending into Lake County. In the southwestern part of this county, are twenty or thirty small lakes which probably give name to the county.

Inside of the circuit of the mountain limestone, space must be allowed for the Parma conglomerate. It is to be wondered that so coherent a formation, though known to underlie the entire coal measures, makes no actual outcrop except in Jackson County. Its place is just northeast of Newaygo, northeast of Rockford in Kent County and north of Bellevue in Eaton County, stretching thence to Springport and Parma in Jackson County.

The result of this determination of the place of the Carboniferous limestone, in the western part of the State, is a considerable westward extension of the area of the Coal Measures. I think the formation may be considered as reaching to Lowell and Sand Lake in Kent County, thence to near the centre of Newaygo County, the southeastern corner of Lake County, the northern part of Osceola County, the southeastern part of Missaukee, the southern part of Roscommon, the northeastern corner of Gladwin and thence to near the mouth of the Rifle River, on Saginaw Bay. On completing the circuit along the eastern and southern boundary, we find it to enclose an area of about 321 townships, or over 11,500 square miles.

It must not be imagined that productive beds of coal exist over all this area. The general attitude of the formation is horizontal, with local undulations. As in Illinois and Indiana, denudation of the anticlinals has removed the productive measures in many places. Artesian borings at Lansing have not revealed the existence of workable beds of coal, though they are seen to outcrop on the west at Grand Ledge, and on the east at Williamston. An abundance of fragments in the drift may safely be taken as an indication of the proximity of a coal-bed, especially if they form a train of small fragments, particles or powder. Such fragments are known to exist over nearly the whole of Montcalm County. One at Greenville was four or five inches in diameter. The same is true of Osceola County. A family in the northern part of this county (S. E. ¼, sec. 6, T. 19, N. 8, W., Hartwick) gathered over a bushel of the fragments within the space of five acres. A specimen shown me was superior Cannel coal, and the remainder was stated to be like it.

Considering that the whole western portion of the coal-field is overspread by an unbroken sheet of superficial materials, known to be over eighty, and probably, in most of the region, nearly 200 feet thick, there is no probability that the actual existence of workable coal will ever be established by any other means than artesian explorations. The art of boring has, in this State, attained so high a degree of perfection, that this method of investigation, though not available for the individual geologist, is eminently practicable for towns, counties or wealthy corporations. It is a species of enterprise, moreover, which ought to be conducted at the cost of the public, as the entire public has an interest in the results.

I think it would be judicious to undertake a boring at any point along the Grand Rapids and Indiana Railroad, between Morley and Reed City. Big Rapids is probably the most eligible spot. Along the Flint and Père Marquette Road, I think borings might prove successful from Reed City to Farwell; along the Detroit, Lansing and Lake Michigan Road, at any point between Ionia and Howard City.

A failure to strike a workable bed of coal at one place would be no presumption against success at another place ten miles distant, unless unexpected developments in the geology should vitiate the reasoning which I have employed. The greatest possible care should of course, be exercised, in noting the nature of the materials passed through.

The likelihood of striking coal is no greater in the valleys than on the hills; but the lower positions would economize expense in boring and tubing, and afterwards, in shafting and curbing.

Vegetable Remains in the Drift Deposits of the Northwest.

By N. H. Winchell, of Minneapolis, Minn.

In the state of Iowa, Dr. C. A. White has described the occurrence of deposits of ancient peat in the alluvium of the river valleys near Davenport and Iowa City. At the former place the peat lies "almost upon the very brow of the bluffs that border the valley of the Mississippi." It is said to be overlain by a yellow clay, or loam, supporting the soil, twenty feet in thickness, containing shells of the genera *Succinea*, *Helecina*, and *Pupa*, and by a bluish-gray clay, three to five feet thick, not stratified, containing shells like those named, and doubtfully the remains of *Elephas primigenius*.[1] Under this peat is a dark-brown soil two feet thick, which lies on a tenacious blue clay that embraces sand, gravel and distinctly scratched boulders, and is of an unknown thickness. The peat deposit at Iowa City was discovered, in digging a well,

[1] Geology of Iowa, Vol. 1. 1870, pp. 119, 339.

at the depth of thirty feet beneath the surface, two miles south of the city. The surface of the ground there is fifty feet or more below the general level of the uplands of the vicinity, on the gentle slope of the valley-side of the Iowa River. In Adair County, in the southwestern part of the state, another similar peat bed has been discovered. This is between two and three feet in thickness. Overlying it is a deposit of very slightly modified drift, if not entirely unaltered, and under it is a dull, bluish bed of clay. This locality is within the valley of one of the upper branches of the Middle Nodaway River, a mere prairie creek.

Dr. White remarks that these deposits were at one time thought to date from pre-glacial times, but refers them now, without hesitation, at least those at Davenport and Iowa City, to post-glacial time. As they occur within the valleys of large rivers, and as the overlying drift materials have rather the nature of alluvium, this assignment is very reasonable. Peat marshes no doubt, existed along the valleys of those rivers, at that period of time, whenever it was, that witnessed their waters much swollen above their present stages, and when they spread over wide lake-like expansions, which were, after the manner of many rivers of the present day, periodically extended and contracted by the varying precipitation and drainage facilities.

Col. Chas. Whittlesey mentions in the "Smithsonian Contributions" (No. 197, page 15), that two logs of resinous timber are reported to have been found in a well sixty feet deep at Iowa City, on the upland, or general level of the country. A bed of sticks and leaves has been observed at Burlington, one hundred feet above the Mississippi River, at a depth of twelve feet.

Two miles east of Lime Springs, in Howard County, peat was found by Mr. James Irving in digging his well. It lies below a heavy bed of sand nearly twenty feet thick. Over the sand is clay. Although this peat shows the impressions of leaves, no sticks were found. It is at least four feet thick and forty-four feet below the surface. At another point, one mile south of Lime Springs, the farm of C. H. Wood afforded a large piece of wood, apparently cedar or tamarack, from the depth of forty feet, in blue clay. At a point seven miles southwest of Lime Springs, logs were found forty feet below the surface in the digging of a well, in the drift clay. These cases are given on the authority of John T. Smith.

In the geological reports of the state of Illinois, mention is frequently made of a black carbonaceous layer, embraced in the drift deposits, resembling an ancient soil frequently associated with remains of vegetation, more or less decayed; and sometimes with a peaty deposit, embracing wood and leaves. An examination of the published county reports of that state, has afforded the following notes on this bed of vegetation.

VEGETATION IN THE DRIFT DEPOSITS OF ILLINOIS.

Jersey County, borders on the Mississippi. In this county fragments of wood, and even trees of considerable size are often met with in sinking wells or in making other excavations in "the plastic clay." By "the plastic clay" is here meant the lowest portion of the northern drift. It is overlain by a layer of twenty or thirty feet of gravel and sand, with boulders. This last is overlain by about twenty feet of yellowish-brown clay rising to the surface.

Marion County. Mr. Henry Englemann reports pieces of brown wood in a well at Patoka, thirty feet below the surface. This occurs in blue clay with sand and pebbles, the clay itself being thirty feet thick.

Cook County. Mr. Henry M. Bannister mentions the occurrence of pieces of wood and stems of small trees in the lacustrine deposits in the vicinity of Evanston, at about eleven feet below the surface. "In one or two instances only has there been observed what appeared to be fragments of decayed wood," in the lower clays of the drift.

In *St. Clair County*, Mr. Worthen found bits of wood in a coarse quicksand near the bottom of the drift, over eighty feet below the surface. This was below the mass of blue and reddish clay, which was fifty feet in thickness.

In *Hancock County*, the drift clays that underlie the central and eastern portion, are said by Mr. Worthen, to contain fragments of wood, and often the entire trunks of trees of considerable size. These woods appear to be species of cedar. This county borders on the Mississippi River.

In *Perry County* Mr. Worthern reports a blue mud, lying below the main mass of drift clay, containing leaves and sticks. This is met in a great many wells, but not in all. Hence he infers that it was either a local deposit that accumulated only in ponds or

sloughs, or else it was in part swept away by surface erosion at the commencement of the drift period. "Its average thickness," he says, "cannot be definitely stated, for when it was found in digging for water, the well was generally abandoned as soon as this deposit was reached, because the partly decomposed vegetable matter which it contained, rendered the water unfit for use. It appears to be composed, in good part, of vegetable matter consisting of leaves and partially decayed wood, embedded in a muddy sediment, and has been penetrated in some places to the depth of five to ten feet. It usually lies at the bottom of the drift deposits, but at one point in Jackson County, it was underlaid by a bed of sand two or three feet in thickness." He regards it as belonging to a period somewhat older than the true drift deposits.

Jackson County is said by Mr. Worthen, to afford the same bed of dark blue or black mud, at an average of about thirty feet below the surface, containing leaves and branches of trees. It is here also below the main mass of the drift clay, but immediately above a water-bearing stratum of sand.

In *Woodford County* a layer of rotten driftwood or peaty matter occurs at the depth of about sixty-five feet, below a thickness of fifty feet or more of bluish clay, or hardpan, exposed in a ravine of Richland Creek, as reported by Mr. H. A. Green. This deposit here is said to resemble peat, but embraces fragments of wood well enough preserved to be recognized. From this locality Prof. Lesquereux identified the following species: American white birch, black or double spruce, American larch or tamarack, and one variety of cedar.

The "true drift" in *Grundy County*, is said by Mr. Frank H. Bradley, to consist of a tough, blue, "boulder-clay," with pebbles and boulders, sometimes also including fragments of wood, overlaid but slightly, or not at all, with gravel, and underlaid, so far as known, with a bed of hardpan, and a water-bearing quicksand, which has thus far prevented any knowledge of the underlying materials.

McLean County. At the city of Bloomington, a coal mining shaft passed through 254 feet of drift materials, including two separate layers of black mould and vegetation, between which, according to the report of Mr. H. M. Bannister, were eighty-nine feet of hardpan and clay. The first layer was thirteen feet thick, and a hundred and ten feet beneath the surface. The lower was but six feet thick.

In *Tazewell County*, according to the last named writer, a bed of black vegetable mould was met in wells in the vicinity of Pekin, where it tainted the water of wells to such an extent as to render them almost unfit for use.

In *Menard County*, Mr. H. M. Bannister reports near Athens, a shaft that struck pieces of coniferous wood at the depth of about one hundred feet below the general level of the country, taken out in a tolerable state of preservation.

In the extreme northeastern part of *Morgan County*, a shaft passed through eighty-five feet of drift materials, the greater portion of it bluish hardpan, and near the bottom encountered a log eighteen or twenty inches in diameter. Logs and driftwood are reported to have been frequently found in the clays, etc., of the drift in this county, according to Mr. Bannister, but seldom as deep as in this instance, at the very base of the formation.

In reference to *McHenry County*, Mr. Bannister says: "In the central and western portions of the county, the mass of the drift appears to consist of clay and hardpan, with occasional boulders. We have, however, in this county, accounts of logs of wood and other vegetable remains being found at various depths in these deposits, a feature which appears to be wanting, or extremely uncommon in Lake County. One such instance of the finding of a cedar (?) log seven inches in diameter, at the depth of forty-two feet below the surface, is reported on the eastern line on Sec. 13, township 44, range 6. Other instances are reported in various parts at depths varying from fifteen to fifty feet or more."

At Sycamore, in *DeKalb County*, Mr. Bannister says large pieces of wood were said to have been met with in the blue clays of the drift, at the depth of fifty feet, in digging a well, and other instances are mentioned at considerable intervals in the drift, in various parts of the county.

In *Fulton County*, Mr. Worthen describes a band of black mould or soil containing leaves and fragments of wood, found below the drift clays in grading the track of a railroad near Canton.

In *Adams County*, the first discovery was made in the state of Illinois, of this ancient soil or layer of vegetable mould, according to Mr. A. H. Worthen; and it was made in sinking a shaft at Coatsburg, in 1859. The mould was met at ninety-one feet. The

overlying drift was mostly a blue clay, with gravel and boulders. Immediately below the black mould, was a stratified blue clay, six feet in thickness. Below that a tough blue clay was penetrated twenty feet.

In *Carroll County*, a well that was dug in the town of Mt. Carroll, revealed a "black, mucky clay," at forty-eight feet. It was itself five feet in thickness. "Another well, some three miles distant, passed through a second soil some three feet below the surface, and immediately thereafter a deposition of timber or wood two or three feet in thickness, many pieces having tenacity enough to hold together for months after exposure to the atmosphere." This is reported by Mr. James Shaw.

In *Lee County*, a similar bed of "black, oozy, marly mud, full of sticks, etc.," is reported by Mr. James Shaw, to have been encountered in digging a well in Palmyra township. This black deposit, containing the decayed remains of timber, lies at or near the base of the true drift, in this part of the state.

According to Mr. Shaw, at one locality in *Whiteside County*, a well was sunk twelve or fifteen feet in yellow, unctuous clay; then blue clay was struck, and in about fifteen feet more a great quantity of sticks and wood, apparently cedar and pine, was found. This woody deposit was about the base of the true drift.

Mr. Worthern reports, that in *Peoria County*, in the city of Peoria, a shaft struck a "black, mucky soil, with limbs of trees," at the depth of a hundred and forty five feet. This black soil was two feet in thickness and was underlain by a boulder clay. The overlying drift here was coarse sand and gravel, with boulders, with a clayey bed forty-eight feet thick, of alternating layers of sand and gravel with boulders.

Also in *Monroe County*, Mr. A. H. Worthen reports. that on Sec. 3, T. 2, S. R. 10 W. a well that was sunk in yellow, drift clay, to the depth of thirty feet, encountered there a black, peaty soil with fragments of wood. This was underlain by seven or eight feet of hard, blue clay.

In *Sangamon County*, Mr. Worthen reports, on the authority of Mr. Joseph Mitchell, a well digger, that it is customary to pass through a bed of black muck with fragments of wood, from twelve to fifteen feet below the surface, having a thickness from three to eight feet, in the northwest part of the county.

Mr. Worthen regards *this* deposit of black mould as later than

the true drift. It lies over the main mass of boulder clay, and just below the loess. It was met in a great many places in Sangamon County, and always above the true drift. He parallelizes it with the chocolate colored band, a foot or two in thickness, seen in the bluffs at Quincy, at the base of the loess. He says: "These two ancient soils, the one at the base of the loess, and the other below the boulder clay, belong to distinct and widely separated periods, and indicate two distinct emergencies of the surface during the Quaternary period, and the prevalence of conditions suitable for the growth of an arboreal vegtation."

If the state of Illinois were divided by parallels running east and west into three belts of equal width, the foregoing counties in which there have been discoveries of this ancient peat or soil, would be found grouped as follows. In the northern third or first belt are Cook, Grundy, McHenry, DeKalb, Carroll, Whiteside and Lee. In the central belt are the following counties: Jersey, Hancock, Woodford, McLean, Tazewell, Menard, Morgan, Fulton, Adams, Peoria, and Sangamon. In the most southern belt, are the counties of Marion, St. Clair, Perry, Jackson, and Monroe. The following border on the Mississippi River: Jersey, St. Clair, Hancock, Jackson, Adams, Carroll, Monroe. Cook County lies along Lake Michigan. McHenry is in the extreme northern portion of the state, bordering on the state of Wisconsin, and Jackson County is within forty-five miles of the extreme southern extremity of the state.

VEGETABLE REMAINS IN THE DRIFT DEPOSITS OF INDIANA.

In the state of Indiana, I have been able to gather the following references to vegetable remains in the drift, from the annual reports of the State Geologist, Prof. E. T. Cox.

In *Franklin County*, Dr. Rufus Hammond mentions, that in digging wells on the uplands, the roots and bodies of trees are frequently found at various depths, from ten to thirty feet; and occasionally limbs and leaves are found with vegetable mould, at various depths.

In *Vermilion County*, reported by Mr. Frank H. Bradley, the prairie between Eugene and Perryville is underlain, at the depth of about sixty feet, with a layer of "soft, sticky, bluish mud, filled with leaves, twigs, and trunks of trees, six to ten feet thick, locally known as 'Noah's barn yard.'"

In *Clay County*, Mr. Cox says, that "trunks and branches of co-existing trees are sometimes met with in sinking wells to the lower stratum of sand and gravel." This stratum of sand and gravel is supposed to be that lying below the main mass of the drift, and near the rock.

In *Dubois County*, Mr. Cox reports, that lacustrine deposits are found when digging wells in the level plateau, in the northwest part of the county between Ireland and Otwell. Near the base of these beds, which consist of clays and impalpable intercalations of siliceous material, interrupted by thin layers of quicksand, "are found the remains of shrubs and grape-vines of enormous growth, indicating perhaps, the luxuriance of a warmer clime."

In *Parke County*, Dr. B. C. Hobbs reports, that in the blue drift-clay, which is there generally underlain by a water-bearing stratum of sand and gravel, are often found large pieces of timber, which have a fibre that bears a strong resemblance to that of cedar and pine.

In *Ohio County*, Mr. R. B. Warder has reported a section of a well sunk on Sec. 6, T. 3, R. 2, W. In that section, at the depth of thirty-two feet, were found rotten leaves, twigs, black soil, and wood with a thick bark, believed to be walnut. These lay below a blue clay, quite hard and without pebbles, and above a layer of nine feet of coarse sand, gravel and fragments from the underlying limestone.

In *Dearborn County*, Mr. Warder mentions a bed of blue clay, at Lawrenceburg, exposed only in time of low water in the Ohio River, containing abundant remains of leaves and logs, pointed out to him in 1871, by Prof. E. Orton, of the Ohio survey. In these remains have been identified the fruit of the Buckeye, Birch, Hickory and Buttonwood. This deposit has also been met in a well at Lawrenceburg, and in another at Aurora.

In *Switzerland County*, is another excellent exposure of the same character, at Hickman's Landing, two miles above Florence. A bed of blue clay, containing leaves and sticks, four and a half feet thick, may be traced in the river bank without interruption for twenty rods, and appears at points above and below. Both here and at Lawrenceburg, ochreous deposits of sand and gravel accompany the blue clay, both above and below. This deposit has been met in wells dug at points more remote from the river, in one instance more than a quarter of a mile away, showing, as remarked

by Mr. Warder, that it is not a recent deposit upon the shore, but that it is older than the terrace which contains it. Mr. Warder regards the deposit at Lawrenceburg, which is twenty or thirty feet lower than that at H'ckman's Landing, as not contemporary with it, but intimates that they are both due to ancient conditions of the flood plain of the Ohio River, and have the nature of drift-wood accumulations.

In *Clarke County*, Mr. W. W. Borden says, that mastodon remains are found in the gravel or altered drift, in the township of Utica, at as great a depth as thirty feet, indicating, in his opinion, the situation of an old river or lake bed. Also in the high lands about Charleston, and on other elevated positions in that town, pine or cedar wood has been exhumed in the sinking of wells.

In *Warren County*, Mr. John Collett has observed vegetable remains. He says: "Near the base of the drift, and resting on a broken and irregular floor of coal measure rocks, is generally found a bed of potter's clay, somewhat intermixed with quicksand and black muck. A marked bed of the latter was met in sinking the West Lebanon shaft. From the soil or peat here discovered, a large number of roots of trees, shrubs and plants of pre-glacial age, were found *in situ*, specimens of which were placed in the State Cabinet."

In *Knox County*, Mr. Collett mentions an unctuous clay, filled with vegetable matter, known as "Noah's cattle yard," as constantly met with in shafts and bores, about Sanborn and elsewhere.

Of these counties of Indiana in which vegetable remains have been observed in the drift, the following are in the central third of the state: Franklin, Vermilion, Clay, Parke and Warren. The remainder are in the southern third, viz., Dubois, Ohio, Switzerland, Dearborn, Clarke and Knox. Some of these are in the extreme southern portion, bordering on the Ohio River. In the northern third portion of the state there is no record of the discovery of peat or vegetation in the drift, in the reports of the State Geologist since 1869.

VEGETABLE REMAINS IN THE DRIFT DEPOSITS OF OHIO.

So far as known to the writer, Col. Chas. Whittlesey published the first authentic information concerning the existence of vegetable remains in the drift deposits of the state of Ohio. Reference is here made to his article in the "Smithsonian Contributions to

Knowledge." No. 197, on the Fresh-water glacial drift of the northwestern states. The localities he names and describes at some length will here be simply enumerated. He remarks that the timber is similar throughout, and that the vegetation extends to all members of the drift. The trees consist mainly of white cedar, but there are also pine, spruce, willow, and other species.

In *Franklin County*, an artesian-well at Columbus, encountered a log in the blue clay at the depth of about twenty-five feet.

In *Ross County*, fragments of cedar, mineralized by sulphide of iron, were taken from a well in clay at the depth of thirty feet; 150 to 200 feet above the Scioto River.

In *Summit County*, a hard, well-preserved and natural specimen of wood, resembling Osage orange, was taken from a well at the depth of forty-two feet, 544 feet above lake Erie.

In *Cuyahoga County*, at Dover, specimens of fine-grained cedar are said to have been taken from twelve feet below the surface, 153 feet above lake Erie. At Cleveland, there is a persistent layer of vegetable remains which renders the water of many wells unfit for use, occurring about eighteen feet below the surface, and fifty feet above lake Erie. This layer is between the "gray sand," and the blue clay, and probably corresponds to that below the loess discovered in the state of Illinois.

In *Hamilton County*. Of fifty-nine wells examined in this county, six had muck beds with evident vegetable débris. These vegetable remains were embraced in clay beds, or were below the blue clay.

At eight miles east of Oxford, in *Butler County*, Mr. David Christy has described an upright stump and the roots of a tree, in the blue clay at the depth of thirty feet.

In *Athens County*, Dr. Hildreth notices several instances of logs in the blue clay, some of them forty feet below the surface.

In *Scioto County*, numerous instances are mentioned of half decayed logs being found in wells on the uplands, from 200 to 400 feet above the Ohio river.

Vegetable remains have also been found, according to Mr. Whittlesey, in the drift in *Madison* and *Stark* counties.[2]

[2] In Vol. II of the Geological Survey of Ohio, Final Report, Dr. Newberry enumerates many of these localities, and adds also a reference to Grand Sable, south shore of Lake Superior, in the state of Michigan, described by Sir W. E. Logan. Geology of Canada, 1863, p. 905. This vegetation lies below 300 feet of stratified sand and gravel. He also mentions the bed at Toronto, described by Prof. H. Y. Hind, consisting of wood at a depth of ten to twenty feet, imbedded in yellow clay.

In *Highland County*, Mr. Edward Orton reports the occurrence in numerous instances of a layer of vegetation and vegetable mould. He says: "A fact of great interest in this connection is, that the uppermost beds of the blue clay give proof of having been a soil in their earlier history. They are discolored by vegetable mould, and mingled with their substance are found quantities of leaves, branches, roots and tree-trunks. In some districts of the county, this forest soil seems everywhere present. It was met with in one instance in wells that were dug on four adjacent or closely contiguous farms. In the village of Marshall, eleven wells out of about twenty that have been dug there, are known to have reached this stratum of vegetable matter. In some instances, the water that is found at this horizon, is so impregnated with the decomposing products, as to be unfit for use.

"The presence in this buried soil of leaves of existing species of forest trees, is vouched for by many careful and well-informed observers. These leaves are identified as those of sycamore, hickory, beech, etc. But by far the largest portion of the wood that comes to light is coniferous, and is commonly pronounced to be red cedar.

"The depth at which this forest soil is met with, varies from ten to ninety feet, but in a large majority of cases it will be found to be between twenty and thirty feet. It is much more frequently met on the high plateaus than in the valleys."

In *Montgomery County*, Prof. Orton also mentions the occurrence of fragments of drifted coniferous wood in the lower drift deposits.

In *Clermont County*, Prof. Orton has given a detailed account of the drift deposits in the first volume of the final report of the Geological Survey of Ohio. Here the "forest bed" as it has been named by the Ohio geologists, pertains to the uplands, and is accompanied with ochreous and irony deposits that sometimes yield forty per cent. of metallic iron. It unmistakably overlies the boulder clay, which is blue, plastic, and filled with striated boulders. Over it is a yellow clay, abounding with gravel, with occasional boulders, the thickness of which seldom exceeds ten feet. The forest bed is sometimes replaced by the iron ore bed; in which case the overlying gravelly yellow clay, is replaced by a whitish clay six to eight feet in thickness. The iron ore bed is found to prevail in the low and flat-lying portions of the county. An extensive area is found in the northeastern portions of the county, which extends through Brown, and into Highland county.

In *Clarke County*, Prof. Orton says, in the western portion it is no uncommon thing to come on these old growths at a depth of twenty or thirty feet below the surface. They occur above the boulder clay and lie below the yellow gravelly clay.

In *Ashtabula County*, Mr. M. C. Read describes and illustrates by a wood-cut, the position of an old swamp lying along one of the lake ridges. It is covered with about six feet of drifted sand, and lies on the boulder clay. Mr. Read says: "This swamp had its origin in the causes which raised the clay ridge into its position, and was evidently filled with swamp vegetation at the time the waters of the lake were resting upon the northern slope of this ridge, the winds gradually carrying the beach sand over the crest of the ridge into the swamp basin, and in time burying it beneath the constantly accumulating sandy deposit."

In *Lake County*, Mr. Read mentions the occurrence of a fragment of wood about eighteen inches long and four inches in diameter, "imbedded in the blue clay, in such a position that it must have been deposited there with the clay." This was about twenty feet below the top of the blue clay, and thirty-two feet below the surface of the ground. This being found within the bluffs of Chagrin river, has been referred by Dr. Newberry, to the recent action of the stream on the bluffs in freshet time, when the current, perhaps bearing along large quantities of ice and driftwood, may have forced the stick into the softened clay.

Of these counties in Ohio in which there are published records of the finding of vegetable remains in the drift, the following are in the northern third of the state: Summit, Cuyahoga, Ashtabula and Lake. There are only two in the central third—Franklin and Stark. The rest are in the southern portion of the state: viz., Ross, Hamilton, Butler, Athens, Madison, Highland, Montgomery and Clarke.

In the state of Wisconsin, I have been able to learn only of those localities named by Col. Whittlesey, *viz.: Walworth County.* From a well eighteen feet deep wood resembling white cedar was taken, 250 feet above lake Michigan (I. A. Lapham).

In *Outagamie County*, at Appleton, specimens of the red cedar were found in a red clay, eighteen feet below the surface, one hundred and fifty feet above lake Michigan; also white cedar from thirty feet below the surface, in the same red clay.

In *Brown County*, specimens of wood, apparently willow, were

taken from the red clay, fifty feet below the surface of Lake Michigan, at Green Bay.

On the authority of G. H. Berkins, a log of "tamarack," over a foot in diameter was found five miles east of Geneva, in *Walworth County*, at the depth of twenty-five feet, in digging a well. Clay was above it, and gravel and stones below.

Of these localities, Walworth County is in the southern portion of the state, bordering on Illinois. The others are in the Green Bay Valley, in the northeastern portion of the state.

VEGETABLE REMAINS FROM THE DRIFT DEPOSITS OF MINNESOTA.

At Albert Lea in *Freeborn County*, which borders on the state of Iowa, a muck is struck in some wells, at the depth of thirty-eight or forty feet, which not only furnishes a water unfit for use, but is reported to contain sticks and other vegetable matter. This muck bed lies below a coarse gravel which extends to the surface.

In Windom township, *Mower County*, which lies next east of the last named county, a bed of peat, accompanied with more or less wood which appears to be white cedar, has been discovered at a depth of about fifty feet below the general level. One large piece of wood was two feet long and ten inches in diameter. The wood lies uniformly on the upper surface of the peat bed. This bed extends over most of the county, having been met in Sec. 13, Pleasant Valley, and also in Bennington and Leroy townships.

Similar deposits of peat have been met in the southwest part of Fillmore County, in digging wells; also in Jordàn township in the northwest part, in digging wells, but the particulars of these localities have not yet been learned.[3] It is only known that this portion of the state occupies a high tract, in some portions forming a dividing ridge that turns the natural drainage north and south — into the Root River, or into the Cedar. The region is one of high prairie. The materials that overlie this peat bed have not been

[3] Since this paper was read the following particulars concerning this bed of vegetation have been obtained in Fillmore County. They were derived from Calvin E. Huntley, of Spring Valley, who has drilled a great many wells in that part of the county:

N. W. ¼ Sec. 6. Beaver Tp. It occurs here in a well dug on a ridge, in a prairie country, thirty feet below the surface, and is two or three feet thick. It lies below blue clay, and over a black clay. Land of Andrew Oleson (Early).

Sec. 2. Sumner Tp., on Wm. Bailey's land. It here lies thirty-five feet down, and consists entirely of wood.

Secs. 29 and 30. Jordan Tp. Wood was taken from wells dug by M. Robins and by Geo. Hare. This is in a high prairie country.

closely observed except at one point — in Windom township. The peat there underlies a gravelly clay, which contains boulders, and has the appearance of being the same as the glacier deposit, known as unmodified drift. The same underlies it. Some portions of the clay above the peat are reported to be blue, while the whole of that which underlies it is of a blue color. The whole county is heavily covered with this drift clay, and some very large boulders of granite lie near the wells that have met this peat.

In *Scott County*, pieces of grape-vine were taken out of the well drilled at Belle Plaine for salt, at the depths of ninety-three feet and at 168 feet. The former was in a clay bed of six feet thickness, embraced in sand, and the latter in gravel and coarse sand.

At Campbell Station, near Breckenridge, in the western part of the state, a piece of wood resembling white cedar was taken from a well drilled five inches in diameter, at the depth of 173 feet.

It is only necessary in closing this paper, to call attention to the singular fact that the geologists of the states of Illinois, Indiana and Ohio, differ in regard to the position of this bed of vegetable remains so common in those three states. Those of Illinois, at least Mr. Worthen, the state geologist, recognize two beds of vegetable remains, one below the loess, and the other below the glacial drift. That below the glacial drift is the most frequently mentioned, and corresponds to that which in the state of Indiana is stated to be *below* the boulder clay. Prof. Orton as emphatically states that the forest bed lies *over* the boulder clay in the state of Ohio, and has dwelt at length on the succession of changes that accompanied the formation and final burial of this ancient soil. He has given an illustrated section of the drift deposits at Lawrenceburg, Indiana, the same locality that has been described by the geologists of Indiana, and *there also* places the forest bed above the boulder clay, at least in deposits that are said to be later than that clay.

The very general interest that is being excited in this country, in the problems that invest the history of the drift, is my only excuse for calling your attention to the prevalence of vegetable remains in the drift of the Northwest, and to the wide divergence of high authorities on the relative position of those remains, in respect to the boulder clay.

On the Parallelism of Devonian Outcrops in Michigan and Ohio. By N. H. Winchell, of Minneapolis, Minn.

It is well known that there is a difference of opinion respecting the age of some of the Devonian limestones of Michigan, Illinois and Ohio. The geologists of Michigan, led by Prof. A. Winchell, have, on paleontological grounds, referred most of the Devonian limestones to the Hamilton, crowding the Corniferous downward, and reducing it to insignificant dimensions, or extending it over the breccia that characterizes the limestone lying next below. On the other hand, Dr. Newberry of the Ohio Survey, has given the name Corniferous to the whole group of Devonian limestones, remarking that the Hamilton characters that pervade the blue limestone are overbalanced by Corniferous characters. The ground taken by Prof. Worthen, of Illinois, is intermediate between these two extremes. He regards the upper portion of the limestones of the Devonian, characterized generally by a blue color and by argillaceous impurities, as the real equivalent of the New York Hamilton. The lower, light-colored limestones, he assigns to the Corniferous and Onondaga of New York state.

The writer has spent several seasons of field-work in each of the states of Michigan and Ohio, his field, in the latter state, lying contiguous to the state of Michigan, and has been able to compare the Devonian limestones as they occur in their natural outcrops, one with another, in the two states, and to follow the strikes of the various members from one state to the other, under the sole guide of lithological evidence. It must be admitted, that until the paleontology of a formation has been exhaustively worked out, when there are no characteristic, reliable typical species universally accepted as authoritative, the surest evidence of the horizontality of separate exposures of rock, is identity of lithology, at least when the localities in question are in adjoining states.

There are three horizons involved in this question of the parallelism of outcrops in the Devonian limestones, which have each a marked and distinctive lithological character. In descending order, the first distinctive horizon is the blue limestone. Disregarding for the present the question whether this embraces the Tully limestone of New York, a point not yet established, taken together it is one of those landmarks in the geological scale by

which the field-geologist reads his bearing and establishes his position in regions that are otherwise very obscure and uncertain. Being a firm and enduring rock, it is more frequently seen in outcrops than any of the other Devonian strata. The second marked and distinctive horizon is that of the crystalline and crinoidal limestone, seen in the quarries at Delhi, in Delaware County, Ohio. This limestone is easily identified from central Ohio to the northern portion of the Lower Peninsula of Michigan. The third distinctive lithological horizon is at the base of the Devonian. It is of an arenaceous character, and sometimes constitutes a layer of white sand six or ten feet in thickness. It is commonly regarded as the equivalent of the Oriskany of New York. The following attempt at parallelizing the Devonian outcrops in Michigan and Ohio, is based on these three horizons primarily, and is intended to express simply lithological resemblance, and inferentially stratigraphical equivalency. In this table is included the Water-lime of Ohio, as it has, in the opinion of the writer been referred wrongly in one of its phases, to the Corniferous. To explain more fully—the Water-lime, as seen in northwestern Ohio, exhibits three distinctly different lithological aspects. One consists of thin-bedded, fine-grained, drab limestone (Phase No. 3), with bedding frequently distorted or wavy; another consists of a harsh, heavy-bedded, magnesian limestone, with wavy bituminous, or carbonaceous films (Phase No. 2). And the third is the well characterized breccia of Mackinac and Put-in-bay Islands, which occurs irregularly and in patches in the formation, obliterating the true bedding and hardening the whole mass (Phase No. 1).

TABLE OF PARALLELISMS OF DEVONIAN OUTCROPS IN MICHIGAN AND OHIO.

	MICHIGAN.	OHIO.
HORIZON, NO. 1. Blue Limestone. *Hamilton.*	Partridge Point, in Thunder Bay, L. Huron. Trowbridge's Dam, Thunder Bay River. Pine River Point, near Charlevoix, L. Mich.	Sandusky, Delaware, Marion. Sec. 17, Defiance, Defiance Co.
HORIZON, NO. 2. Crinoidal Limestone. *Corniferous.**	Top of the Bluff at the head of Cheboygan L., in Presque Isle Co. Little Traverse Bay (Top of the bluff, halt 862). Top of the Bluff at Sunken Lake, Presque Isle Co.	Marblehead, near Sandusky. Delhi, Delaware Co.; Sulphur Springs, Del. Co. Mouth of Flatrock Cr., Paulding County.
HORIZON, NO. 3. Sandstone, and Arenaceous Limestone. *Oriskany*†	Raisinville, Monroe Co. Base of Crawford's Quarry. Base of Bluff at Sunken Lake.	Grand Rapids of the Maumee, Wood Co. Independence, on the Maumee R. Near the bottom of quarries at Bellevue, Sandusky Co. Charloe, Paulding County; Whitehall, Lucas Co.
Water-lime Breccia. (Phase No. 1.)	Mackinac Island; Gros. Cap L. Mich; Pt. aux Peaux. L. Erie.	Put-in-Bay Island, Wood County; Tiffin, Seneca Co. (part).
" { Thin beds, fine grained. (Phase No. 3).	Light House, Mackinaw City; Otter and Plumb Creeks, Monroe Co; Bois Blanc. I., Waugoshance Point. "Halt 855," Little Traverse Bay.	Fremont, Sandusky Co; Lima, Allen Co; Upper Sandusky, Wyandot Co; Tiffin, Seneca Co. (part).
" { Heavy beds, coarse grained. (Phase No. 2.)	Foot of the bluff at head of Cheboygan L., Presque Isle Co; Monroe Co.	Bottom of the quarries at Bellevue, Sandusky Co.; Charloe, Paulding Co; New Rochester, Wood Co.

* The crinoidal limestone, Horizon No. 2, elsewhere designated in Ohio the Delhi limestone (see Report on Delaware county), is underlain by a harsh, evenly-bedded, buff limestone, which in its upper portion sometimes becomes eminently fossiliferous with corals, and bituminous, though usually resembling the heavy-bedded, coarse-grained phase of the Water-lime. It seems to have taken the special name of "Coenostroma Beds" when thus filled with corals in Michigan. (See "Michigan"—p. 60).

† The "Agatiferous Conglomerate" at the base of Mackinac Island, lies below the breccia, and cannot be the equivalent of this sandstone.

Physical Geology of Lake Superior. By Chas. Whittlesey, of Cleveland, Ohio.

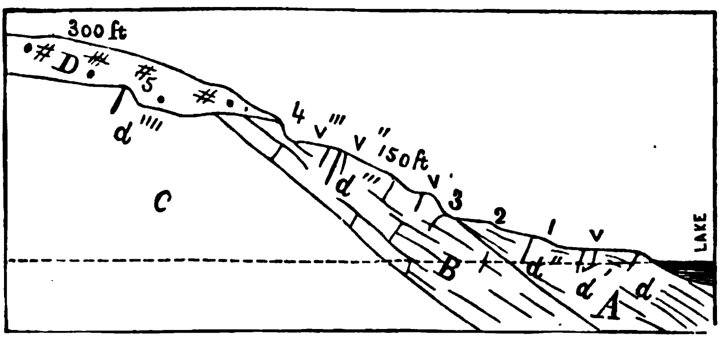
ABSTRACT.

An outline sketch of the trap, Potsdam, sandstone, the Huronian or Azoic slates and the granitic centres of the American portion of the Lake was exhibited to the section (see reduced map herewith, and note). On this are large arrows showing the dip of the copper-bearing beds towards the Lake on both shores. Four general profiles across the Lake were shown on another sheet, numbered one, two, three and four, commencing at Point Keweenaw and Isle Royale on the east. No. 2 passes through the Misery River region and Silver Mountain, all bearing northwest and southeast, at right angles to the basin of the Lake. No. 3 cuts the Apostle islands and Montreal River, and No. 4 the west end of the Lake near Duluth.

There are ten local profiles on, or near the general ones, showing the mode of protrusion of the trap overflows through the Potsdam sandstone. (See cuts inserted below.)

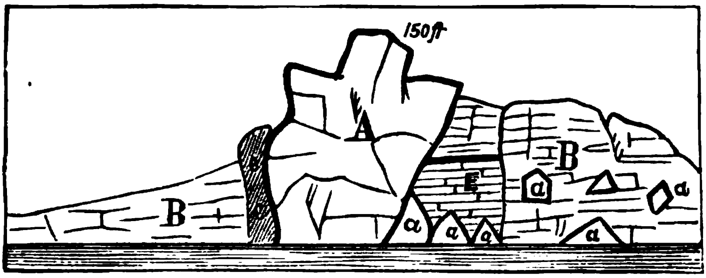
On the American side I have not met with well defined Laurentian masses except in the Vermilion Lake region. The great central masses of granite and syenite around which the Huronian slates, quartz and trappose masses are formed, do not meet the

PROFILE OF THE ROCKS UP HOLLOW ROCK CREEK, NEAR PORTLAND, G OF MAP—COURSE NORTH-WEST THREE MILES.



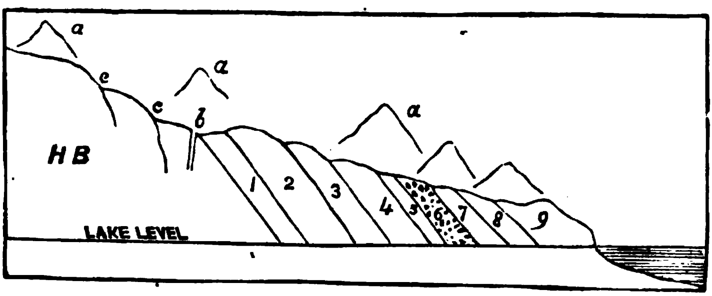
A, Amygdaloidal trap and altered slaty sandstone—dip Southeast by East 12 to 18 deg. B, Close-grained dark-blue trap—dips East 12 to 25 deg. C, Dark colored mass, in places slaty, like the hornblende slate of St. Louis River. D, Clay and boulder drift. d, d', d'', d''', d'''', dykes. v, v', v'', v''', Spar veins, 1, 2, 3, 4, 5, chutes in the stream.

INTRUSIVE QUARTZ AND BASALT IN HORIZONTAL COLUMNS, J OF MAP—TWO MILES EAST OF LOW BUSH RIVER.



A, Dyke of quartz 80 to 100 feet thick. a, a, Blocks of quartzite intruding into the trap B. B, Trap, bedded horizontally. E, Columnar trap, horizontal, pentagons 2 to 3 ft. in diameter. e, e, Brecciated mass and spar.

PROFILE OF THE ROCKS ON THE MANIDOWISH RIVER, K OF MAP—COURSE NORTH-WEST. DISTANCE EIGHT OR TEN MILES.



a. a. a., Peaks of quartzite and greenstone, 300 to 900 feet above Lake. H. B., Hornblende Rocks resting upon sienite and granite. c. c., Falls of the Manidowish. b., Trap dyke.

1. Bed of red trap 200 feet thick. 2. Bed of hornblende rocks, 1,000 feet thick. Huronian. 3. Bed of red trap, 200 feet thick. 4. Bed of coarse, variegated, altered sandstone, 100 feet thick. 5. Bed of red, flinty, thin bedded trap, 25 feet thick. 6. Bed of coarse, red, trap breccia, 50 feet thick. 7. Bed of altered, shaly sandstone, 20 feet thick. 8. Bed of altered sandstone, thickness not seen. 9. Bed of amygdaloid trap, red, breccia and altered sandstone, in alternate beds extending into the Lake at least 2,000 feet thick. Dip not regular, varying from 5 to 15 deg. Southeast.

descriptions of the Laurentian given by the Canadian geologists. A comparison is given in the following table: —

COMPARISON OF THE LAURENTIAN ROCKS OF CANADA WITH THE SO-CALLED AMERICAN LAURENTIAN.

Canada.	Michigan.
Mica schists predominant; gneiss and gneissoid rocks. Crystalline limestone in contorted beds—topography low mountain ranges. In the Adirondacks diallage and hypersthene rocks, with high mountain peaks. The formation characterized by magnetic iron ore, in veins and masses.	Sienitic rocks predominate in irregular domes of various height, occasionally granite; mica schists rare. In some instances bunches and irregular veins of quartz with sulphurets of iron, copper and lead. No masses of iron—no crystalline limestone. **Wisconsin.** Sienite, granite in domes, and rarely Hornblend slate—trap eruptions and dykes rare. **N. East Minnesota.** Sienite, granite and mica schists with gneissoid rocks; rarely basaltic dykes.

The difference in the rocks as above represented is too great to allow them to be classed as one geological formation.

These crystalline rocks are for convenience called granitic although there are intercalations of hornblendic rocks, and rarely of dykes, and of bunches of quartz. The prevailing rocks in those most ancient of all the rocks of Lake Superior, are granite and syenite alternating without any apparent regularity.

There is so great a similarity in the analyses of lava, eruptive trap, and the older granites, that I am forced to the conclusion that they have a common origin, and if any of them represent the central mass of the earth in a state of fusion, all of them do. This question enters into my verbal references to the map and profiles, in discussing the process of upheaval, of the copper-bearing series. With the origin of these rocks the connection is obvious.

The primordial granites represent the slow cooling process of the central mass, and thus became highly crystalline. The intrusive trap beds represent the dynamical results of subsequent pressure, upon the central mass caused by cooling and contraction.

Dykes and volcanoes represent a feebler, more recent and less general mode, of the same action; as the contraction lessened. There is in this later form of action, which is local, no capacity to raise mountain chains. These are due to corrugations of the crust acting in general slowly, but giving rise to an interior compression that is irresistible. This would find relief along the lines of least resistance, but would not by any means always reach the surface. As soon as water was formed, sediments were immediately and rapidly laid down, in the depressions; giving rise to the stratified rocks; and this process, together with the hardening process of cooling, continually gave strength to the crust of the earth. The weight of the sedimentary rocks, in the opinion of Professor Hall, has in places been sufficient to sink large areas, and thus create both valleys and mountains.

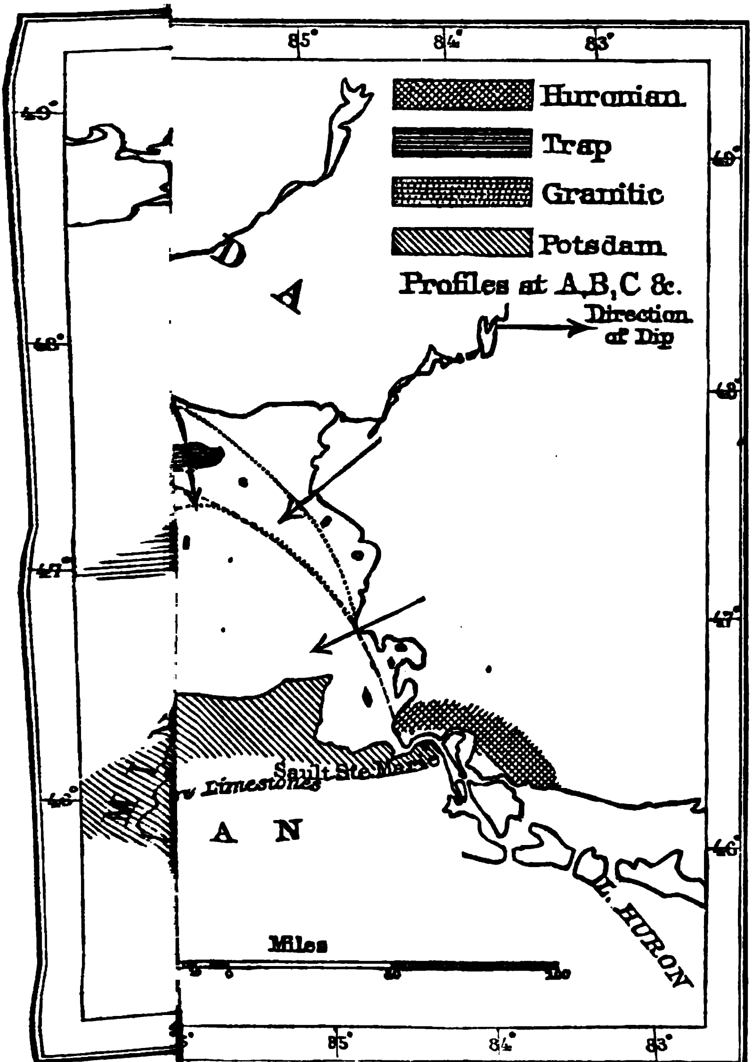
I adopt the conclusions of Messrs. Foster and Whitney, and of Dr. Owen, that the traps of Lake Superior are eruptive overflows which took place during the deposit of the Potsdam sandstone.

It is remarkable that these outbursts should have occurred, in the form of the rim of a basin or trough of such magnitude; forming a complete circuit. The extent of the included area is likewise remarkable.

In some instances, as in the Marquette region, and on the Menominee River, the eruptive rocks have pushed up through the Huronian beds, cutting them and the Potsdam at the same time.

ANALYSES OF TRAP ROCKS FORMING A PART OF THE MARQUETTE COUNTY HURONIAN.

NUMBER.	LOCALITY AND PHYSICAL CHARACTERS.	WATER.	SILICA.	ALUMINA.	MAGNESIA.	LIME.	IRON.	OXIDES.	SODA AND POTASH.	AUTHORITY.—REMARKS.
1	Presque Isle, Marquette Co., Michigan, compact; magnetic.	9·53	38·24	1·48	14·83	1·43	34·40	Per. and Prot.	Trace.	Foster and Whitney.
2	Light House Point, Marquette, tough subcrystalline.	—	49·318	11·709	5·028	2·798	26·542	Prot.	4·603	Prof. H. S. Douglass, Mich. University—(Na. K. H. and loss, not separated).
3	One-half mile north-east Jackson Forge, north-east quarter, Sec. 28, compact diorite; light green.	—	48·911	15·156	6·156	5·762	10·72	Prot.	13·945	Prof. Douglass—(Na. K. H. and loss, not separated), bunches of copper pyrites in this rock.
4	Cleveland Mine Negaune, Marquette Co., "green rock" passing into specular iron ore.	—	51·800	26·600	5·642	—	14·40	Prot.	1·588	Prof. Douglass—Last item not separated as before.
5	Same mine; compact "green rock."	1·04	66·80	3·50	2·40	—	17·90 Per.	5·00 Prot.	3·35	Prof. J. L. Cassels, Cleveland Medical College.
6	North Line, Sec. 2, T. 47, R. 27, Marquette Co., "green rock" subcrystalline.	1·30	59·20	3·60	Trace.	9·60	Prot. 5·05	Per. 16·75	4·50	Prof. Cassels.



Huronian
Trap
Granitic
Potsdam
Profiles at A,B,C &c.
Direction of Dip
Sault Ste Marie
Limestones
A N
L. HURON
Miles

Between the Canadian and the American, Huronian series the resemblance is very close; as may be seen in the following contrast.

A COMPARISON OF THE HURONIAN ROCKS ON BOTH SHORES OF LAKE SUPERIOR.

CANADA.	MICHIGAN.
Silicious and conglomerate schists — clayslate —jasper conglomerate and quartz beds very heavy—rarely specular iron ore in veins. Crystalline trap, carrying copper and iron pyrites in quartz veins.	Silicious schists, fine grained crystalline limestone and quartzite, in flattened masses. Earthy, compact and crystalline trap, charged with iron ore segregated in irregular masses, specular and magnetic. WISCONSIN. Silicious schists on the Menominee; same on Bad River, with belts of quartzite and hornblende, rocks, slaty and crystalline. The relation of the hornblendic division (IIa) on Bad River is much closer with the Huronian than with the copper-bearing rocks (see tables of analyses herewith). Color various, charged with iron oxides; compact and crystalline trap rare. On the Menominee, crystalline sandstone; on Bad River none. Specular and magnetic iron ore. MINNESOTA. Dark colored silicious slates valley of the St. Louis; eruptive rocks, faults and dykes, frequent.

Here a close resemblance is manifest between the Huronian systems, on the Canadian and American sides of the Lake. On both shores they lie beneath the Potsdam sandstone and above the granitic or Laurentian series.

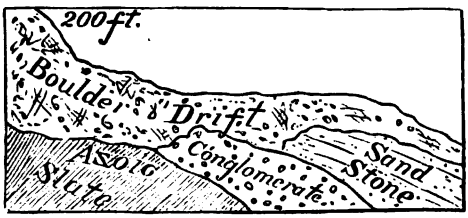
There are, however, minor differences in the excess of slates and iron ore on the American side with less marble, but the general characters are closely alike.

For the present, I insert a belt of Huronian age, underneath the copper-bearing trap of Point Keweenaw, from Mt. Houghton to Long Lake in Wisconsin, although it does not come to the surface, between Torch Lake and the Akogebe Lake. The indications that it exists not far beneath the southern crests of the trap series in this space, are numerous.

On this theory, the intruding beds and masses of trap were forced out into and over the Huronian, in places raising the entire series and in others breaking through the incumbent Potsdam, then in an unconsolidated state; and in many instances overflowing the Potsdam beds. The same thing occurred on the north shore during the Potsdam era, but the enclosed portions were less and the metamorphic action comparatively greater.

There are two classes of conglomerate—one due to littoral shore action, as at the Falls of St. Louis River (see profile at F), which

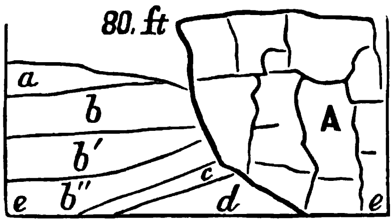
FALLS OF ST. LOUIS RIVER. F OF MAP.



Junction of the sedimentary and metamorphic rocks, St. Louis River, Min. Angular fragments of slate in the conglomerate.

is limited; and another to friction, connected with the uplifting movements more general and prolonged, but analogous to the breccias, which may be seen alongside of dykes on the north shore. Instances of the last form of conglomerate are shown in the profiles at Presque Isle, Marquette (A), and at the Falls of the Amin-

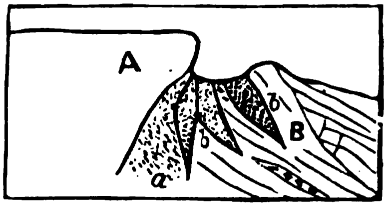
PROFILE A—NEAR MARQUETTE—TRAP PENETRATING SANDSTONE AT PRESQUE ISLE.



A, Protrusion of trap. *a*, Drift. *b*, *b*′, *b*″, Red sandstone bedded—soft or shaly—lower part altered. *c*, Semi-breccia. *d*, Altered sandstone, with reticulations of quartz, calc-spar and chlorite. *e*, *e*, Lake level.

icon, Douglass Co., Wisconsin. Where the protruding trap masses are heaviest, and of course the upheaval and the friction greatest, there the conglomerates are found in greater strength.

FALLS OF AMINICON RIVER, DOUGLASS CO., AT E OF MAP, NORTH AND SOUTH, LOOKING WEST.



A, Trap overflow projecting over B, bedding or stratification dips to the south. *a*, Broken and brecciated mass. *b*, Conglomerate with trap pebbles and semi-breccia. B, Red and gray sandstone with coarse silicious grains, tilted locally away from the trap but in a few rods level.

The boulders of trap are larger in this variety, than in those due to the water-washed gravel of beaches.

No heavy conglomerates, with trap pebbles and boulders, are to be found, except in or near the trap uplifts. The conglomeratic portions of the sandrock, with quartz pebbles, are generally near the base where it rests on the Huronian, and where it sometimes contains fragment of the azoic rocks, showing conclusively an aqueous deposit. The other form of conglomerate shows as conclusively its mechanical origin by friction. Neither the conglomerate nor the sandstone carries copper, except in or near contact with copper-bearing trap. In all cases in this region the trap is the primordial source of the copper, and where the eruptive masses are destitute of sulphur, it appears in its native form.

None of the conglomerate beds are continuous over large spaces, but pass into sandstone, with few pebbles, or with none. Neither are the trap beds continuous, but die out along the line of outcrops, being replaced by beds or flattened masses of a different variety, by sandstone and by conglomerate. They probably die out in depth also.

On the north shore the entire copper-bearing series from Duluth to Pigeon River is cut by trap dykes, which are generally columnar and by outbursts of intrusive greenstone and feldspathic masses. Here the intercalated beds of sandstone and conglomerate are thin

and limited. There are on both shores altered layers of sandstone between beds of trap, with ripple marks in perfect condition.

I cannot admit that the red sandstone of Lake Superior belongs to two formations. The period of its deposition was a long one, but there was no break in it, and no intervening beds; except the trap.

Between 1845 and 1860, I examined in canoes, or Mackinaw boats, frequently more than once, all the exposures which the shore line exhibits from Sault St. Mary to the west end of the Lake, and along the north shore to Two Island River.

Also the profiles of all the streams capable of canoe navigation, with many that are not, and the country between. The cliffs of red, shaly, and often mottled sandrock, between Marquette and Huron Bay, cannot be separated lithologically from those on the north shore of Keweenaw Bay. That those between Grand Island and Marquette are Potsdam, is shown by the overlying Chazy and other lower silurian strata. That the Keweenaw Bay series is of the same age is shown by the outliers of Trenton limerock, reported by Messrs. Foster and Whitney, and shown in my general profile No. 2, near Sturgeon River, about twelve miles west of the head of the Bay.

On the west, the sandstone of St. Croix River in Wisconsin, through which there are trap protrusions at Taylor's Falls is clearly shown by Dr. Owen to be Potsdam. This has been traced up the St. Croix to the waters of the Black and Nemadji Rivers in the valley of the St. Louis River, and to Duluth. On the Poplar and the Aminicon Rivers it is the same, and among the Apostle Islands.

There are everywhere variations in the thickness and hardness of the beds, and in color changing from light to dark red, and from gray to mottled red and gray; but the general aspect of the series is the same. Progressing eastward, on the Bad River, and the Opinike, it is occasionally visible. On the Montreal, opposite the Islands, its dip has been reversed from slight *southeast* to *northwest;* at angle almost vertical where it shows a thickness of more than 10,000 feet. It can be examined across the edges in the channel, every foot of it laid bare. Coasting still to the east the strike carries it outward into the lake till we pass the Porcupine Mountains, where the entire mass has been pushed northward, by the immense thickness of the trap, which is twelve or fifteen miles.

Beyond this, in the valley of the Ontonagon and thence along the coast, between Flint Steel and Elm Rivers, is a repetition of the variable shaly beds of Keweenaw Bay, which almost meet across the range in the gap of Portage Lake. There are places where contiguity to the trap, especially on the lower faces of overflows, it shows much metamorphism, and even an apparent change to amygdaloid trap; but these are local and limited, and do not require a forced theory, for their explanation. Where the trap of Point Keweenaw comes out to the lake between Eagle River and Copper Harbor, the main body of the sandstone lies beneath the lake, and the conglomerate portions form the shore.

BOHEMIAN RANGE.

Messrs. Foster and Whitney, and their assistants, particularly Mr. S. W. Hill, made a thorough reëxamination of the Bohemian Range in 1850—1851. They describe this range as extending to the westward until it sinks below the country in the neighborhood of Portage Lake. The rocks composing it come more nearly into the category of the Huronian, than the trap series. The lower parts are close grained, flinty, chloritic, compact, porphyritic and crystalline. Transverse veins exist there, which carry copper and iron pyrites, like those at the Bruce Mines in the typical Huronian of Canada.

The glacial movement coming from the northeast along the entire copper range, its southern faces often formed a lee under which the drift materials collected, and thus the base of the system on that side is generally covered from view.

Some clear profiles were made however, extending across the point from shore to shore, all of which exhibit a synclinal along the Bohemian Range, which a sharp dip locally to the south, including the upturned edges of the sandstone. There is generally along this line a band of friction conglomerate, with the usual evidences of metamorphism, where sandstone passes gradually into jasper, vescicular trap, and breccia in patches (see F. & W., vol. I, p. 64). In the case of a sandstone bed at Eagle Harbor on the north side of the Point, which is overlaid by amygdaloid trap, the alteration of the sandrock extends into it several feet, where it resembles scoriaceous trap.

On the southwest flank of Mt. Houghton, is the brick-red porphy-

ritic trap, which furnishes the boulders of the friction conglomerates, dipping to the southwest. It does not differ from the intrusive masses to the south of Carp Lake, which, pushing outward, formed the protuberance of the Porcupine Mountains.

In respect to displacement by force, and the tilting of the sandstone, the evidence is the same for those beds around Lac La Belle and Gratiot Lake, as it is on the opposite side of the Point. These sandstone beds cannot be separated lithologically from those on Tobacco River, the Entry, and the Ance. The metamorphism is less extensive, but the instances I give of eruptions, through sandstone at Presque Isle, and on the Aminicon River, prove that such effects may, in some circumstances, probably while the sandstone was yet soft, extend only a few rods.

It is very rare that the horizontal sandstone rises more than 200 feet above Lake level. The uplifted masses seldom rise to more than 1,000 feet, and never more than 1,200; but in depth, the elevating force must have been deep seated; many thousand feet.

Westwards towards Portage Lake and beyond that gap in the Range till we reach the waters of the Ontonagon, the uplifts are not as bold or regular. Here along the southerly side of the Range the line of fracture is generally concealed. An exposure may be seen on the headwaters of a tributary of Torch Lake, called "Trap Rock River," described in F. and W., part I.

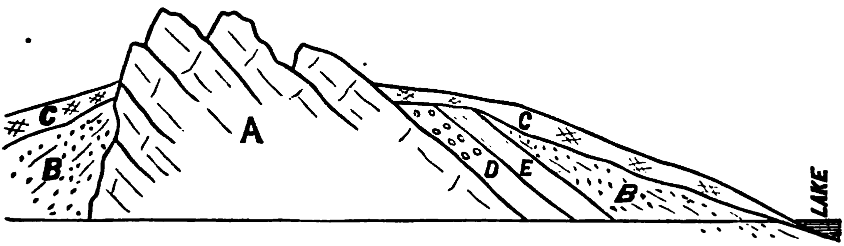
The exposures on the line where the trap beds meet the sandstone, on the north side of the range about Portage Lake, and westward on the waters of Salmon-trout, Elm and Misery Rivers, are not frequent, but the sandstone strata of the coast on that side and in the channels of those streams, presents the same series of changeable, soft, shaly, red, gray, and mottled rocks, with harder and more solid beds, coming in and tapering out, as are seen on the flanks of the Huron Mountains between Presque Isle and Cypress River.

Between Portage Lake and the Ontonagon, in the valley of Keweenaw Bay, to the south of the Range, the Silver Mountain has been pushed up about 1,000 feet in the form of an upward fault of no great length, dipping north, but bold and sharply cut. It exhibits on the south the usual features of brecciated, crushed, and altered fragments. (F. & W., part I, p. 68.)

Around the forks of the Ontonagon where the south side beds are better exposed, the evidences of violence and dislocation often become manifest. The epidotic mass known as the "Calico Rock,"

is nearer a breccia, than anything else. An unpublished profile (D of map) which I made across the Range in 1846, about five

PROFILE AT D OF MAP, FIVE MILES WEST OF ONTONAGON. COURSE NEARLY NORTH AND SOUTH—LENGTH TWELVE MILES.



A, Intrusive trap in heavy beds dipping northerly 25° to 30°. B, Potsdam red and gray sandstone both shaly and compact; dip on the north next the trap rapid, but at a distance nearly horizontal; on the south for a short distance quite sharp and then horizontal. C, Red laminated drift-clay—100 to 500 feet thick. D, Red conglomerate. E, Fine-grained black slate—lamina parallel to the dip of the bed. There are bands of sandstone and conglomerate intercalated with the trap.

At Iron River between the slate E, and conglomerate D, is a band of silver bearing quartz now being wrought.

miles west of the forks, shows the contact between the calico rock and the sandstone on the south. Their relations to each other are precisely the same as that of the porphyritic and jaspery masses at Lac La Belle. The edges of the sandstone are tilted up sharply to the south very much disarranged, but soon reassuming a horizontal position.

Up the west fork towards Akogebe Lake, of which it is the outlet, the exposures have the aspect of eruptive masses, along a line parallel with the trap range.

Not far beyond the Akogebe Lake, according to Messrs. Brooks and Pumpelly of the Michigan Survey, the Huronian rocks appear beneath the trap about 4,000 feet in thickness, against which, on the south, the horizontal sandstone of Keweenaw abuts, unconformably. Not having been over the space between Akogebe and the Montreal, on the line of the Huronian, I can add nothing in regard to the profile of the Report, except that it is hypothetical and furnishes no observed contact.

My explanation of the upheaval of the entire range from Keweenaw Point to the waters of Bad River, is, that it is due first to the intrusive Huronian belt, connecting beneath the surface from the west end of the Bohemian, to the vicinity of Akogebe

Lake, whence it is visible to the westward underlying the range to Long Lake, more than one hundred miles. From Iron River, fifteen miles west of the Ontonagon, to near Bad River in Ashland county, Wisconsin, a distance of about eighty miles, the trap series has an enormous thickness of ten to fifteen miles, a large part of which is red and porphyritic, in which the proportion of sandstone and conglomerate is small. The effect of an intrusive mass, forcing itself between the older crystalline rocks below and the trappous series above, could be no other than what we observe.

The trap beds tilted and forced northward, carried the overlying sandstone beds upward and forward, until they approached the vertical, as they do along the channel of the Montreal River, showing a thickness of two miles. West of the Bad River the trap series diminishes more than one-half, and although the underlying Huronian remains the same, the sandstone on the north is less disturbed, remaining at a lower level, in the valley of Bad River, nearly horizontal.

Prof. Irvine reports a low synclinal commencing at the falls of Bad River, which extends west, parallel with the range, into Bayfield Co., where the trap comes to the surface through the sandstone as a flat undulation. I can testify to a disturbance along this line in the sandrock, but did not follow up the examination, so far as to discover the cause.

If the trap beds on the south had not lost their thickness by 10,000 or 12,000 feet, this low wave would doubtless have risen into a mountain range.

The conglomerates where they are cut by the Montreal, the Opinike, the Bad River, and by the outlet to Bladder Lake, exhibit the usual signs of metamorphism near the trap; in streaks, bunches, and irregular veins of calc-spar and quartz.

There are evidences of later and successive ejections of eruptive matter, which in the basin of Lake Superior continued through a long period of geological time.

NOTE.—Owing to the small scale of the accompanying map the space occupied by limited and narrow formations is very much exaggerated, and their boundaries misplaced. This is especially so at and around Marquette, where some connection has been attempted but with limited success.

THE PHYSICAL STRUCTURE OF THE OHIO COAL FIELD. By CHAS. WHITTLESEY, of Cleveland, Ohio.

ABSTRACT.

THIS is principally an exhibit of a rough map with profiles and verbal explanations. On an outline plan of the Alleghany coal field north of the Kenawha River, including the states of Ohio and Pennsylvania, the general outcrop of the Pittsburg seam of coal is traced dipping towards the medial line of the basin. The direction of the dip of this and other coal seams is shown by arrows pointing inward, on which is written the bearing and the rate per mile.

In Ohio I have determined by levels and triangles the direction and the rate of dip, in about fifty instances, forty of which are here given, the sides of the triangles ranging from two to fifty miles each. Ordinarily the lines are eight to fifteen miles in length, because these distances give the best results. If the sides are less than five miles the local irregularities of the beds may be so great, that the true inclination will not be obtained. If the lines are too long the sphericity of the earth is a source of error. In most of the triangles I have constructed, the sum of the sides is about thirty miles, which is the best of dimensions. The length and the bearings of the sides are found by the use of local and county maps. The elevations were obtained by using canals and railroads as bases, thence to the outcrops of beds, and to mines; by the spirit level, in some of its forms; never by barometer.

These methods are subject to slight errors which geodetic work, such as is made use of in England, France and Austria, would avoid, but the errors of map triangles, must to a certain extent correct each other; and are far more reliable than mere opinion, based upon surface observation.

In the recent survey of Ohio, all modes of determining the precise dip of the beds, by applying mathematics and geometry, to perfect physical geology, are ignored. As the inclination is very slight it is absolutely necessary to apply such processes, to prevent the confounding of strata. Neither the number nor extent of the beds can be determined without it.

The following table gives a summary of the results which I have obtained, during the past thirty-five years, beginning at the Ohio River on the south and proceeding in order northward and east-

ward, to the Pennsylvania line. It is a transcript of the figures written on the stems of the arrows of the map.

RESULTS OF TRIANGULATIONS FOR DIP, BEGINNING AT THE OHIO RIVER NEAR PORTSMOUTH, THENCE NORTHERLY AND EASTERLY TO THE PENNSYLVANIA LINE.

NUMBER.	LOCALITY.	GEOLOGICAL STRATUM.	DIRECTION OF GREATEST INCLINATION.	RATE PER MILE IN FEET.
1	Scioto Co.	Logan Sandstone.	South 57° East	40.
2	Lawrence Co.	Coal Seam.	" 60° "	20.
3	Ross Co.	Waverly.	" 83° "	32.
4	Pomeroy.	Coal Seam.	" 80° "	29.
5	Gallia Co.	Coal Seam.	" 73° "	27.
6	Columbus.	Cliff Limestone.	" 81° "	22.
7	Haydenville.	Nelsonville Coal.	" 79° "	36.
8	Straitsville.	Nelsonville "	" 78° "	33.
9	Shawnee Run.	Nelsonville "	" 77° "	25.
10	Sunday Creek.	Nelsonville "	" 74° "	32.
11	Moxahala.	Nelsonville "	" 62° "	30.
12	New Lexington.	Nelsonville "	" 60° "	30.
13	Tunnel.	Nelsonville "	" 67° "	24.
14	Jonathan's Creek.	Nelsonville "	" 66° "	21½.
15	Zanesville.	Limestone (local).	" 87° "	48.
16	Coshocton Co.	Coal Seam No. 6.	" 26° "	22.
17	Crawford Co.	Waverly.	" 59° "	5½.
18	Valley of Mohican.	Coal No. 1.	" 53° "	2½.
19	New Philadelphia.	Limestone (local).	" 86° "	10.
20	Bolivar.	Limestone (local).	" 72° "	25.
21	Wayne Co.	Coal No. 6.	" 82° "	16.
22	Massillon.	Coal No. 1 (local).	" 71° "	15½.
23	Stark Co.	Coal No. 1 (local).	" 23° "	9.
24	Sandy Valley.	Coal No. 4.	" 43° "	36.
25	Summit Co.	Coal No. 1.	" 53° "	8½.
26	Cuyahoga Co.	Berea Grit.	" 8° West	11.
27	Lorain Co.	Berea Grit.	" 34° "	9.
28	Geauga and Trumbull.	Conglomerate.	" 37° East	5½.
29	Portage and Trumbull.	Coal No. 1.	" 12° "	20.
30	Conotten Valley.	Coal No. 6 (local).	North 80° "	14½.
31	Mineral Point.	Coal No. 6.	South 32° "	16½.
32	Mahoning Valley.	Coal No. 1.	" 22° "	14.
33	Mineral Ridge.	Coal No. 1 (local).	" 18° "	16½.
34	Lowell.	Coal No. 1 (local).	" 37° "	13.
35	Rochester, Columbiana Co.	Coal No. 6 (local).	" 10° "	30.
36	Hanover, Columbiana Co.	Limestone.	" 20° "	16.
37	Salineville, Columbiana Co.	Coal Seams (local).	North 70° to " 82° "	80 to 100.
38	Hammond's Station, Col. Co.	Coal Seams (local).	South 50° "	57.
39	Steubenville.	Pittsburg Seam.	" 37° "	23.
40	Wheeling.	Pittsburg Seam.	" 45° "	53.

By inspecting the map, it will be seen that the Waverly strata, and the conglomerate below the coal, dip regularly to the east, southeast, and south, beneath the coal-bearing rocks. The floor of the coal series, though irregular, is flatter than the seams of coal, limestone, and iron ore of the series; which are not conformable, but dip at a sharper though at a low angle. These irregularities and this want of conformability, are not here the result of mechanical disturbance since the deposition of the coal; but are due to irregular deposition. On the Pennsylvania side of the trough, there have been flexures due to the rise of the Alleghanies; the number and extent of which are described by Rogers. The axis or medial line of the trough, representing its deepest parts, which is shown in red lines bears about northeast and southwest, and is parallel to the general crests of the Alleghany Mountains. It lies to the east of the valley of the Ohio, but it is parallel with the general course of the river from Beaver, Pa., to Pomeroy, Ohio.

I also exhibit four profiles; A, B, C and D, extending across the field from the southeasterly rim in West Virginia and Pennsylvania, at right angles to the axis, based upon personal observations and the reports of those states and Ohio.

I have besides made five profiles through the northwestern part of the field in Ohio, from a point on the medial line in western Pennsylvania, radiating to the west around to the north, which are not shown in the plan.

Most of the recent survey in the northeastern part of the Ohio coal field, remains as yet unpublished; but as far as reported there are four flexures or undulations laid down.

The axes of these reputed undulations in the strata, are shown by my red lines, and are all of them nearly north and south, and therefore parallel to each other. Of these four, the one which crosses the Ohio near Marietta, is probably due, not to mechanical elevation, but to unevenness of the floor, and the irregular distribution of the materials of the series.

Of those reputed to exist farther north, I find no proof of their existence. If they had an existence, as mechanical flexures, due to the rise of the Alleghanies, they should be parallel to them, and not have as to them, the bearing of an acute angle.

The profiles I exhibit represent the number of coal seams in different parts of the basin, especially on its opposite sides. Their number differs materially in the different profiles, and in different ends of the same profile; showing conclusively that they are not continuous.

THICKNESS AND NUMBER OF SEAMS, ALLEGHANY COAL-FIELD.

UPPER COAL MEASURES.				LOWER BARREN MEASURES.			LOWER COAL MEASURES.			
LOCALITY.	OBSERVERS.	NUMBER OF SEAMS.	TOTAL THICKNESS IN FEET.	LOCALITY.	OBSERVERS.	THICKNESS.	LOCALITY.	OBSERVERS.	NUMBER OF SEAMS.	THICKNESS.
Morgantown, W. Va.	Rogers.	6	315	Morgantown, W. Va.	Rogers.	377	Alleghany River, Pa.	Rogers.	13	450
Pittsburg, Pa.	Rogers.	—	260	Beaver Co., Pa.	Rogers.	370	Cheat River Valley.	Rogers.	11	685
Wheeling, W. Va.	Briggs.	—	426	Belmont Co. Rush Run.	Mendenhall.	534	Yellow Creek, O.	Whittlesey.	9 to 12	750 to 800
Belmont Co., O.	Dille.	5	440				Conotten Valley, O.	Reid.	8	378
Conotten Valley, O.	Reid.	7	386	Harrison Co., O.	Reid.	334	Muskingum Co., O.	Andrews.	11 to 13	550
Muskingum Co., O.	Andrews.	4	350	Muskingum Co., O.	Andrews.	140	Zoar, O.	Newberry.	7	660
				Millersburg, O.	Newberry.	383	Holmes Co., O.	Newberry.	6	377
				Black Creek, Holmes Co., O.	Newberry.	350	Vinton Co., O.	Andrews.	7 to 10	416
				Wayne Co., O.	Newberry.	373				
				Gallia Co., O.	Andrews.	210				

Note:—All coal seams of a foot or more thickness are counted.

It is the same with the other strata of limerock, iron ore, sandstone and shale, that go to make up the series. The conglomerate, or its geological equivalent, is found regularly at the base of the series everywhere, but in the hundreds of local profiles already reported, there is a general disagreement, both in the number and character of the beds. Uniformity instead of being a rule, is a very rare exception. The great Pittsburg seam, is the most persistent and reliable stratum of the series; bût beneath this there is not a single bed of the series that is continuous over large spaces. Towards the bottom, especially at the northwest, in the region on which the reports are still wanting, this want of irregularity is more prominent than elsewhere.

This irregularity, the flatness of the beds and the small space between them, renders attention to physical geology indispensable. Its complications and the true position of the coal seams, can be discovered in no other way.

A thorough investigation in that line, will demonstrate that the beds in northeastern Ohio are not persistent in any direction, and that it is a fundamental error to attempt to harmonize them on the theory of undulations.

1st. Because if there are dynamical waves in the strata, having relations to the Alleghany system, they should be parallel to the axes of that system, and must extend to the Waverly system below the coal.

2nd. There can be no undulation without producing a reverse dip on the outer side of the flexure, that is to the west and northwest.

3d. In a region where the profiles show rapid changes in the number of the strata, that fact is a sufficient explanation of all visible irregularities.

4th. The difference between a true and a false conclusion, as to the structure, is material in a practical as well as a scientific sense, because the number and the position of the coal seams, and therefore their value, is affected by it.

Profile A.A., cuts across the northerly end of the series from Brownsville, Pa., to Akron, Ohio. In the valley of the Monongahela, the lower coal series does not come to the surface. The number of coal seams in the upper series, according to Rogers, is five.

Profile B.B. From Monongahela City to Massillon is so near

the line of A.A., that it does not differ essentially, and will be passed over.

Profile C.C. From Morgantown, West Virginia, high up the Monongahela Valley to Millersburg in Holmes County, Ohio, in the valley of the Kilbuck, shows both the upper and lower series. At Morgantown and vicinity, the lower barren measures can scarcely be said to exist, which in some of the profiles separate the upper and lower productive measures. Here the thickest barren ground is 204 feet, with another of 195, with coal seams above and below both, *four* above the Pittsburg seam and *eleven* below, or *sixteen* in all.

Profile D.D. From Charleston, West Virginia, to McArthur's Town, Vinton Co., Ohio, cuts across the basin still farther south and shows the entire thickness. In the valley of the Kenawha the investigations do not as yet show the upper series or the lower barren measures. There is a space of about 300 feet in thickness below Charleston, in which no coal is known; and below which there are *seven* beds. Above it I have seen *seven* seams, either lying flat or dipping northwest, one of which should answer to the Pomeroy seam, which Professor Andrews regards as the same as the Wheeling and Pittsburg seam. But which of them or whether any of the upper beds, corresponds to the Pomeroy, on the Kenawha, is by no means settled.

The heavy bed now wrought at Pocatolico or Raymond City, is regarded by some geologists as the same as the Pomeroy, rising to the southeast. Provisionally the total number of seams on this line may be called *fourteen*, but the stratification of the upper series is very irregular.

The outcrops on the Virginia side of the basin, differ in many respects from those on the opposite or northwest side in Ohio, but require more investigation before these differences can be dwelt upon with much confidence. Below the lowest coal, is everywhere on this side a heavy sandstone conglomerate, which is often wanting on the Ohio side.

Crossing over to Pomeroy the rock above the coal is a heavy sandstone, differing entirely from the overlying beds of the great seam at Wheeling and Pittsburg, which are bastard limestone. The lower barren measures do not here constitute a marked feature, and are as doubtful as at Charleston, and at Morgantown, being only about 250 feet thick. Below this, in Gallia, Jackson, and

Vinton Counties, there are *five* to *seven* coal seams, the lowest of which rests on conglomerate, or on the Logan sandstone. Profiles in different places show that the beds of coal are not strictly continuous, and the same in regard to limerock, sandstone, and iron ore.

Here my system of triangles for dip commences, using all the strata that are capable of identification at distant points, from the Waverly up to the upper coal beds. These carried forward through Ohio show *no case of a reverse or northwesterly dip* in any bed of the series, which could not have escaped exposure, in so many lines, profiles and plans ; if it existed. The inclination is uniformly east, southeast, and south in direction, but is quite various in the rate per mile.

But for the present I continue my references to the *lower barren measures.* This name originated with the Pennsylvania and Virginia geologists, under the direction of the brothers Rogers, thirty-five years since. Where they first developed the idea in Western Pennsylvania, the Pan Handle of Virginia, and on the Ohio from Pittsburg to Wheeling, this barren ground next below the great Pittsburg seam, is from 350 to 530 feet thick, and is a very marked horizon. It is heaviest at the mouth of Rush Creek, between Steubenville and Wheeling, where it is 534 feet thick, principally of sandstone, carrying no show of coal. Twenty-five miles northwest in Harrison County, Ohio, Prof. Reid makes it 320 feet, and forty miles west, in Guernsey and Muskingum Counties, the thickest barren space is only 143 feet, according to Prof. Andrews, and no greater than many other barren spaces. Southward from profile C.C., it ceases to be a prominent or reliable horizon, which casts doubt on the identity of the Pomeroy with the Pittsburg seam. Below it, on the Wheeling profile, are *seven* or *eight* seams of coal, and on the Yellow Creek, A.A., *eight* to *eleven.*

ON THE GEOLOGY OF THE SOUTHERN COUNTIES OF NEW YORK AND ADJACENT PARTS OF PENNSYLVANIA; ESPECIALLY WITH REFERENCE TO THE AGE AND STRUCTURE OF THE CATSKILL MOUNTAIN RANGE. By JAMES HALL, of Albany, N. Y.

ABSTRACT.

THE object of this paper is mainly to state and illustrate the results of four years of labor, chiefly in the Southern counties of New York and the adjacent northern portions of Pennsylvania, by Mr. Andrew Sherwood, assisted by Mr. Clark Sherwood, under my direction.

The question had been raised regarding the existence of the Old Red Sandstone, or Catskill Group, within the limits of New York, although a considerable area had been thus colored on the original geological map of the State.

The assertion of the non-existence of this formation in the State, had induced me many years since, to review some portions of my work of 1844, and while in the main features it was found correct, it became evident that something farther was needed in the elucidation of the structure of the Catskill region. In fact, it became evident that one could travel from Schoharie County to Pennsylvania line, on rocks of the Chemung group, without touching or seeing the Old Red Sandstone. And from this circumstance arose the statement of the absence of this formation from the State of New York. It became a very different matter, however, when one crossed the same region of country from east to west.

After several visits to this region, and notably one in 1857, with Sir William E. Logan and Andrew C. Ramsay (the latter now Director of the British Geological Survey), the question of the Geological Age of this great accumulation of strata assumed a still more important aspect; and the question had never been lost sight of; though for many years it had been quite impossible for me to undertake the investigation.

Referring to the Geological Map of New York, of 1843, a large area is colored as Catskill Group without indication of Geological structure. A similar feature was seen in Northern New York; where the limits of the Laurentian system had barely been determined. Geological Surveys have been carried on with too much haste, and under the pressure of necessity, from limited time;

therefore it was, that we were compelled to content ourselves with determining the limits of formations, and not the structure, which required long and careful investigation.

In 1870, when for the first time I was able to give attention to this part of the country, there was no definite knowledge of the region; the record of the Geological Map had been controverted, and a denial of the existence of the Catskill or Old Red Sandstone, within the State of New York, was the prevalent opinion.

Mr. Sherwood was employed to begin his investigations in the Spring of 1871, and has continued till the close of 1874. To accomplish the work represented on the map before you has, therefore, cost the labor of two men for four years. It now presents the aspect of a piece of work completed, except that from the erroneous maps of the State we are unable to give more than the approximate limits of the outcrops.

The work has not only accomplished what was undertaken, but has proved conclusively, the existence (first suspected in 1857) of higher formations, lying upon the red Catskill rocks.

The entire region, from the base of the Catskill range to the western limits of the red rocks, in Chenango County, presents a series of nearly parallel anticlinal and synclinal folds; and the same structure is continued to the western limits of the State, although the red rocks may not appear within the State; and the formation probably thins out entirely, before reaching the western boundary of New York and Pennsylvania.

The topographical sketch presents a view of the Catskill range from the east side of the Hudson River, opposite to Catskill, looking over the shales of the Hudson River Group. In this view the general dip of the rocks is perceptible in their inclination to the southward.

In a cross section of this range, as shown in the accompanying diagram, the dip of the strata to the northwest and southeast is shown, forming synclinal and anticlinal folds, of which five synclinals and six anticlinals are included in the extent given.

The expression of the map in its coloring, shows the direction and extent of certain belts of red rock, which in some part of their extent are crowned by gray sandstone and conglomerate, referred to the Vespertine and Umbral formations of Professor Rogers, and are regarded as belonging to the Carboniferous age.

These belts are the synclinal axes, which sometimes embrace

the higher rocks within their folds, and have, in some localities, been so far eroded as to leave only a narrow belt of red rock, and even this has been in many places removed, and the erosion has penetrated deeply into the rocks of the Chemung Group.

Going to the south of the State line, these synclinals carry outliers of the coal-measure, greater or less in extent, as shown by the map. In the Catskill region the general direction of these synclinals and adjacent anticlinals is from southwest to northeast; but farther to the westward they gradually decline in abruptness, and assume a more nearly east and west direction.

The anticlinals are everywhere valleys, along which the streams flow and the main roads of the country are made; the road from Kingston to Delhi being the principal exception. In going to the east or west of these we ascend over the rough and broken country formed by the outcropping of the Red Sandstone and Conglomerate. Owing to the great difficulty of crossing this country, we have long remained ignorant of its geological structure. The synclinals everywhere present high and broken ridges, and more especially so when the Vespertine and Umbral rocks form the terminal mass.

It is true that the Delaware and Susquehanna Rivers both flow across or through these synclinals, in channels made by deep erosion.

The parallel ridges of the high country culminate in the Catskill Mountains, where we have an elevation of nearly four thousand feet above tide-water. The cause of this greater elevation is shown to be due to the convergence of three synclinals, which, presenting such a mass of material to the eroding forces, has prevented the anticlinals from being excavated below the red rocks of the Catskill formation. To this condition we are indebted for the higher portions of the range, which present, in a topographical aspect, only an irregularly scattered mass of mountain elevations.

The section exhibited, crossing the Catskill range from Schenevus to Glasco, is on a line south of the culminating ridges, and therefore does not present the highest points of the range. The lower rocks of the section are of the Chemung Group; but the relations of all these are shown on the smaller section from the Mohawk to Carbondale.

The lower beds shown, of Portage and Chemung, have a thickness of more than two thousand feet; while the red rocks above,

which may be referred to the Catskill, are about three thousand feet thick, and the higher beds, of Vespertine, extending to the summit of Round-Top, may be reckoned at about eight hundred feet.[1]

The passage from the red rocks to the Gray Sandstone and Conglomerate is gradual, with alternations of red and gray rocks, and does not afford any strong line of demarcation.

The remains of *Holoptychius*, in the form of bony plates, fragments of bone, etc., extend through a thickness of more than two hundred feet.

In its western extension, the red rock, with its alternations of green and mottled beds, shows a gradual thinning, and finally seems to be lost entirely.

One of the greatest difficulties met with, in this investigation, has been the occurrence of red and greenish shales in the Chemung and Portage beds; and the finding of gray beds with Chemung fossils at an elevation of at least one hundred and fifty feet above the base of the red rocks, which had always been referred to the Catskill formation.

We have finally, however, ascertained, as I believe, the limits of the formation, and though not always in strong contrast with the rocks below, we have been guided both by physical and biological conditions.

In the interval between well marked Chemung and typical Catskill, there are beds of intermediate character, and we sometimes find a few fossils of the lower rocks. The same means of distinction do not occur in all localities. In some places the indications of the Catskill are in the red shales and diagonally laminated sandstones. In other places we find a mass of vegetation with or without the presence of the large Lamellibranch, known as *Cypricardites Catskillensis*. The occurrence of this fossil may, in my opinion, be relied on as characterizing the base of the Catskill formation, while the *Holoptychius* marks the beds above, but still is not known above the middle of the formation.

Another question, involved in this investigation, has been the determination of the relations of these red rocks to the superior sandstones and conglomerates, which in eastern New York and Pennsylvania are known as Vespertine and Umbral. The question

[1] That the entire mountain elevation above tidewater does not exceed four thousand feet, is due to the dip of the strata, which makes the elevation so much less than the thickness.

also as to the character of these latter rocks in their western extension, is one of great interest, and whether the Waverly sandstones of Ohio may or may not be a continuation of the former.

In some localities in the border counties of western Pennsylvania, the rocks regarded as the Waverly Group of Ohio, rest directly upon the Chemung; and the fossils of the Chemung pass into the higher beds and mingle with other species regarded as carboniferous forms.

Indeed, from the little I have seen, I should say, that in the region referred to, there are more species of fossils passing from the Upper Chemung into the Waverly formation, than there are species passing from the lower to the upper division of the Chemung Group proper.

The question is of great interest in view of the supposed horizon of carboniferous forms; but if we are able to substantiate the foregoing proposition, I think it will be shown that the Chemung fauna continued its existence till after the appearance of carboniferous forms, and that the two faunas, if they can be properly so regarded, lived in the same sea and at the same epoch; and the question of the limits between Devonian and Carboniferous formations, is likely, at least for some time, to remain undetermined in some parts of the country.

The map before the Association I regard as expressing our present knowledge of the extent of these formations, and the structure of the country occupied by the same.

The work is still unfinished in the western part of the State; but we have indications of what we may expect to find on farther investigation.

A comparison between the Ohio and West Virginia sides of the Alleghany Coal-field. By E. B. Andrews, of Lancaster, Ohio.

In the study of the Alleghany coal-field it is necessary to have some defined geological horizon to serve as a datum line with which to collate the various strata. Sometimes the underlying formation—conglomerate in western Pennsylvania and Waverly in Ohio—is taken for such base line, and measurements are made

to the strata above, and the coal-seams are lettered or numbered accordingly. But the conglomerate is an uncertain formation and the Waverly presents a very undulating and uneven surface, as shown by Mr. M. C. Reed and myself in the Ohio Geological Reports.

In this discussion I prefer to take the horizon of the Pittsburgh seam of coal as the base of measurement.

This seam is of wide extent, being 225 miles long and about 100 miles wide, and easily recognized by geologists. It has been asserted that this seam was formed in a trough with the Alleghany mountains forming a sloping side on the one hand, and the Cincinnati uplift on the other, and as the subsidence — which is conceded to have been regular and uniform — continued, the marsh, with its accumulated vegetable matter, crept up either slope. In time the centre or lowest part was buried by sediments, and new land surfaces were formed on which vegetation grew, and other resulting seams of coal stretched across the trough, from side to side, like the chords of an arc, but all coalescing with the great seam ever rising along the margin to meet them. I know of no proof whatever that the Alleghany mountains were uplifted just before the era of the upper coal-measures, nor is there any that the slope on the side of the Cincinnati uplift differed at the time the Pittsburgh seam was formed from what it had been during the era of the lower coal-measures. There is, furthermore, no proof that the upper and lower coal-measures are unconformable, as they must necessarily be if the theory controverted be true. Moreover, as a matter of fact, in Ohio, in locations which I have carefully examined, where the seams above the Pittsburgh seam are said to coalesce with the latter, there is no such coalescing, but the seams continue westward long distances beyond the points where the union is supposed to have taken place.

Disregarding, therefore, the discredit attempted to be thrown upon the great Pittsburgh seam as exceptional in its mode of formation, I shall confidently assume it as a trustworthy datum line to guide us in our investigations.

This seam occupies nearly the centre of the northern and wider part of the Alleghany coal-field, and extends through portions of Pennsylvania, Ohio, and West Virginia. It does not reach Kentucky, its limit of extension to the southwest being not far from the mouth of the Guyandotte River in West Virginia.

Now, if we take this seam of coal and follow around its line of outcrop and measure from it down to the base of the Productive coal-measures, we find the intervals quite uniform through the larger part of the circuit. In Ohio, according to Dr. Newberry's measurements and my own, it is from 700 to 800 feet. In Pennsylvania, on the Alleghany River north of Pittsburgh, it is reported by Prof. H. D. Rogers, to be from 600 to 700 feet; or 800 feet including the conglomerate underneath. In the northern part of West Virginia, a little south of the Pennsylvania line, it is reported to be 500 feet. But in West Virginia, farther south, the interval is far greater, as will be shown. If we make a section across the whole coal-field, including the Ohio side of the synclinal axis, taking the general line of the Kanawha River, we find the south-eastern side of that axis not only very much wider territorially, but also containing a much greater thickness or depth of Productive coal-measures. The Pomeroy seam of coal, which I have shown in the Ohio Geological Reports to be identical with the Pittsburgh seam, dips to the southeast under the Kanawha River a little above its mouth. A few miles higher up the river it reappears on the other side of the synclinal axis, and has been identified by Prof. W. B. Rogers and others. From this point we descend the geological series in going to Charleston, or perhaps to a point a little above Charleston, through an interval estimated to be 700 feet. Professor Fontaine, who has contributed some valuable articles to the "American Journal of Science" on the Geology of West Virginia, writes me that he thinks it may be greater than this.

From Charleston to the Kanawha Falls we descend in the series from 1,000 to 1,200 feet. I measured the interval between the coarse conglomeratic sandrock of the falls and one of the upper coal-seams on Cotton Mountain, a seam which is believed to dip below the river a little above Charleston, and found it nearly 1,200 feet.

Prof. Fontaine estimates 1,200 feet as the thickness of the coal-measures between the top of the sandrock of the falls and the southeastern outcrop of the measures up New River. A thousand feet have been measured, and he estimates 200 feet for a space not measured.

This makes a total of 3,100 feet from the horizon of the Pittsburgh seam to the base of the Productive measures. This is exclu-

sive of 2,132 feet of lower shales and limestones, the Lewisburg limestone, according to Prof. Rogers, being 822 feet thick. This limestone is perhaps local, as Prof. J. P. Lesley makes no mention of finding it in his investigations in Tazewell, Russell and Wise counties, to the southwest, where he found the lower coals and underlying Devonian rocks caught in curious lines of faults and upthrows, which have brought to the surface lower Silurian limestones.

But the Lower Carboniferous limestones appear in full force farther southwest in Tennessee. We have, therefore, about 2,400 feet more depth of Productive coal-measures below the Pittsburgh seam in West Virginia than in Ohio and Western Pennsylvania. My own personal explorations on the tributaries of the Kanawha, and on the upper waters of the Guyandotte and of the Tug fork of Big Sandy, led me to the belief in a corresponding thickness of coal-measures in all that portion of the State extending southwestward to Kentucky.

Perhaps the most valuable range of bituminous coals in the United States is that belt, which, beginning upon Elk River, passes the Kanawha between Charleston and Kanawha Falls, includes the Coal-river field, and crosses the Guyandotte, the upper Twelve Pole, and Tug and Louisa forks of Big Sandy. This belt belongs, geologically, to a space in the vertical series, which is below the horizon of the base of the coal-measures in Ohio and Western Pennsylvania. Yet below this group comes in another, which Prof. Fontaine designates as the Conglomerate series.

If we replace the strata, now included on either side of the synclinal axis, in their original horizontal position, we find the proof of a vast depression of the surface in this portion of West Virginia at the beginning of the series of Productive coal-measures.

It was doubtless a trough, a geosynclinal, according to Prof. Dana's nomenclature, and a part of the great Appalachian system of the wrinkling and folding of the continent. To the southeast there were at the time elevated lands of older formations, stretching along the same Appalachian line of disturbance and upheaval.

On the northern and western side of this vast basin lay the marginal plateau of the Waverly more than 2,000 feet high, with the yet higher lands of the Cincinnati uplift in the distant western background.

This trough had somewhere a connection with the ocean and gradually sank below the water, while at the same time the rivers from the highlands, more or less remote, brought in sediments of various kinds. The sands and muds sometimes accumulated so as to be above the water, and during intervals of repose in the subsidence, vegetation crept out over the newly formed surfaces and formed great marshes, which when subsequently buried, gave to mankind seams of coal. The spaces between the seams of coal were at first chiefly filled with sand which now constitute the massive sandrocks which characterize the whole region of the lower coals of West Virginia. Sometimes the sands were coarse and gravelly, and formed true conglomerates. The conditions favorable to the formation of limestone did not exist, and in the lower 2,000 feet of accumulations, I have seen, in all my extended explorations of the region, only a single limestone layer, and that in Webster County, on the head of Elk River. I had no opportunity to examine it for fossils.

When at last, in the subsidence, this basin was filled, the waters came over the marginal plateau to the north and west, a region remarkable for its stability and for the uniformity and evenness of its subsidence. At first, over the newly submerged space was spread a more or less continuous sheet of coarse sand and gravel which now constitutes the coal-measures conglomerate of Ohio and Western Pennsylvania. The continuity of the sheet is often broken, and large areas around the margin of our Ohio coal-field show no conglomerate whatever. The first coal marshes grew in the hollows and depressions of the Waverly, depressions formed, it may be, wholly or in part, by erosions from surface drainage during the long period in which the formation had remained high and dry land. After the whole plateau had been submerged the same process of filling up, and marsh-forming and coal-making, went on, as has already been described, with the exception that the waters were more habitable, and the layers of fossiliferous limestone show the remains of crinoid, mollusk and fish.

Less sand and more mud was brought in and shales abound, although sandstones are not uncommon, even those that are conglomeratic in character. The Pittsburgh seam of coal, which I have used as my basis of measurement, was by no means the last in the upward series. There are above it in West Virginia, probably 1,200 to 1,500 feet of coal-measures' rocks, with several seams

of coal. This would give from 4,300 to 4,500 feet of Productive coal-measures in that favored State. No other State in the Union contains so great a vertical range, so far as we now know.

This great Kanawha basin or trough originally extended to the south or southwest so as to include the area in which the coals of Montgomery County, Va., were formed, for these coals are doubtless the equivalents of the lowest on New River, as are also the remnants and outliers of coal in Tazewell, Russell, and Scott Counties.

The subsequent upheavals and erosions have thrown great difficulties in the way of determining the course and extent of this ancient trough. I have no sections along the southeastern side of the coal-field in Kentucky—for these we must look to Prof. Shaler, now engaged in the prosecution of the Kentucky Survey—but in Northern Tennessee, on the same side of the field, Prof. Safford reports about 2,500 feet of coal-measures above the horizon of the Mountain Limestone. It is impossible, in the absence of sections through Kentucky, to determine whether these 2,500 feet in Tennessee were formed in a trough of equal depth with that on the Kanawha. It was doubtless approximately so, and we have here a clew to the direction of the trough to the southwest.

If the Lewisburg, West Virginia limestone, is the equivalent of the Mountain Limestone of Tennessee, we may infer that this formation, wherever it existed along the line of the geosynclinal depression, was carried down, while the lower Carboniferous Limestone of Ohio and Northeastern Kentucky, on the northwestern side of the synclinal axis, were not involved in the movement. In Southern Tennessee, Prof. Safford reports in one of his sections only about 800 feet of coal-measures above the Mountain Limestone, the upper 1,700 feet having doubtless been removed by denudation. If not thus removed, the limestone was not carried down in the geosynclinal, but remained on the higher margin as in Ohio, and the original trough by which connection was had with the sea lay probably to the east.

Did the same geosynclinal trough extend in the opposite direction from the Kanawha Valley, *i. e.*, to the northeast through Pennsylvania? If the equivalency of the Pittsburgh seam has been rightly determined in the Cumberland and Broad Top coal-fields, we have in the former, according to Mr. Tyson, 1,100 feet of productive measures below that seam, and in the latter about

700, according to Prof. Lesley. Prof. Lesley has recently reported finding in the Broad Top field thin coals in the Lower Carboniferous, in strata which he regards as equivalents of the Waverly Berea grit of Ohio. This is a discovery of the highest interest, but it will not affect this discussion, since I confine myself to what we term the Productive coal-measures. The geological interval between the middle of the Waverly, with the Chester Limestone above, and these measures, is a very great one. It may be remarked, in this connection, that there are doubtless areas where the lowest portions of these measures contain no register of themselves in seams of coal, the conditions of coal-making not existing, but we have so little definite information on this point that it appears to be necessary to make our limit of depth the lowest known coals of the proper coal-measures. It is quite possible, for example, that the shales, etc., between the lowest known coal-seam on New River, West Virginia, and the Lewisburg Limestone, may somewhere contain seams of coal, but it is not best in this paper to assume the existence of such facts.

In the anthracite coal-fields of Pennsylvania there is so much uncertainty as to equivalents of the Pittsburgh seam that I fear we shall gain little or nothing from them to bear upon the question of the original depth of the basin in which they were formed. Prof. Lesquereux, in his chart of grouped sections in the fourth volume of the Kentucky Survey, places all the coal-seams of Wilkesbarre, Pittston, Scranton and Carbondale, below the horizon of the Pittsburgh seam. In the Pottsville region Mr. Daddow claims that seam G. is the equivalent of the Pittsburgh seam and is 650 feet above the lowest seam in the series, one imbedded in Conglomerate. If we accept this equivalency we find no proof of the existence of the deep geosynclinal trough in that direction.

If, again, the Conglomerate of Western Pennsylvania and Ohio, were once one and continuous, as the Pennsylvania geologists affirm, then, since to the west, the Conglomerate was not deposited until after the great West Virginia trough was filled, and the waters in the general subsidence came over the great marginal plateau already described, we may well infer that there could not have been an extension through the anthracite region of the geosynclinal valley. There was only enough of greater depth to include the increased thickness of the Conglomerate.

The comparison of the two sides of the Alleghany coal-field

suggests a very great difficulty in regard to the determination of the place of what is termed the Coal-measures Conglomerate. Is there an established horizon for such Conglomerate in American geology? In Ohio we are now in the habit of calling the rock the Conglomerate which, when found at all, lies upon the Waverly (although formerly the *Waverly* Conglomerate was also thus designated), and is approximately from 600 to 800 feet below the horizon of the Pittsburgh seam of coal. The same conglomerate extends under the bituminous coal-field of Western Pennsylvania and holds the same relation to the Pittsburgh coal. This conglomerate horizon should have the same relative distance below the Pittsburgh seam in West Virginia, and I think I have found lithological proof of it in a very coarse conglomerate on Elk River, a branch of the Kanawha which enters the latter at Charleston. At the Kanawha Falls is a conglomerate more than a thousand feet lower in the series. This rock has been honored with a capital C, and the coals in the 1,200 feet below it are spoken of as the Conglomerate series. Still below this series and below all the coals, Prof. W. B. Rogers finds another conglomerate in the New River Valley, as does Prof. Lesley under the lowest coals in the faults and upthrows to the southwest. Now if the Coal-measures Conglomerate is a geological horizon and not merely a rock, then these various strata cannot all be the true Conglomerate. We find conglomerates everywhere in the vertical range of the Coal-measures. They are found even above the horizon of the Pittsburgh seam.

Heavy conglomerates abound along the western side of the Eastern Kentucky coal-field at various elevations above the lower Carboniferous limestone and the same is true in Tennessee.

In the Indiana and Illinois coal-field, the coal-seams of which have never been synchronized with those of the Alleghany coal-field, we have reported a Conglomerate or Millstone grit, but no one knows its exact place in the great time scale, or whether it is the equivalent of any of the half dozen well-marked conglomerates of the Alleghany field. So far as we now know it may have no equivalency anywhere.

In Arkansas there is a conglomerate, called in the Geological Reports, the Millstone grit. The available coals of the State are said to be below it, and are therefore called the Sub-conglomerate coals, although Prof. Lesquereux asserts that they belong to the

true coal-formation and cannot be separated from it. The conglomerate, in this case, can have nothing more than a lithological significance.

In the South Joggins' coal-field, at the head of the Bay of Fundy, Sir Wm. Logan reports 14,570 feet of Coal-measures. In this vast series of strata, and not very far from the middle of it, Dr. Dawson, in his admirable work on Acadian Geology, finds a group of coarse sandrocks which he denominates the Millstone Grit series. Here the millstone grit is not known to be the equivalent of the Millstone Grit of Great Britain nor any of our conglomerates of the United States.

In view of this confusion, I think all will agree with me that the terms *Millstone Grit* and *Coal-measures Conglomerate* should either be used to designate a uniform horizon in the Carboniferous system or be abandoned as geological terms and retained only for their lithological value.

I close this paper with another remark by way of inference, viz.: that there is need of an entire revision in the classification of the coal-seams of the great Alleghany coal-field. It seems odd to begin in the middle of the vertical series and call a seam of coal No. 1, or letter A, and enumerate upward while all the seams below are left without enumeration. But the data for such revision are not yet sufficient.

Existence of Glacial Action upon the Summit of Mt. Washington, N. H. By C. H. Hitchcock, of Hanover, N. H.

Mt. Washington, in New Hampshire, 6,293 feet above the sea, is the highest eminence in the North American area swept by ice in the Glacial era. Hence observers have examined it carefully with reference to the discovery of evidences of ice action; because it has seemed to stand alone in the midst of the glacial sheet, and enable us to place bench-marks upon it to show the height of the flood. The unanimous consent of all observers previous to the present moment has been in favor of its isolation in the glacial sea, the ice reaching different altitudes according to different

authors. In 1842 my father described, before this Association, the striation and embossment of the ledges near the Lakes of the Clouds, about 5,200 feet above the sea. Holding the theory of submergence, he supposed Mt. Washington to have been an island in the midst of an arctic sea full of icebergs, but that we had evidence of no other island in New England than this. I have heard him say often, that its present appearance, covered by numerous angular fragments split off the ledges by the action of frost, illustrated forcibly what the general aspect of the whole country would have been, had not the ice removed the débris and ground up the transported fragments into earth suitable for the growth of vegetation. I am not aware that any author has described the glacial phenomena upon this mountain essentially different from that just mentioned, while others have held different theories to account for them.

In 1870 I had occasion to visit the mountain and discovered transported pebbles of rock foreign to the neighborhood, at the height of 5,800 feet. My notes state that the ledges above these pebbles exhibit the usual appearance of embossment produced by glacial agency, the force having come from a northwesterly direction, but no striæ were seen upon them. At that time the only buildings upon the summit were the Tiptop and Summit houses, with the stables. The railroad corporation had not built their depot and scarcely any of the large stones had been turned over, so as to permit one to see the character of the earth beneath. In fact it was supposed generally that the summit presented only an underlying ledge, strewn over with immense angular blocks, which had not been transported any appreciable distance, save as they had rolled down hill. Those who have seen this summit can recall from memory, far better than words can express, these piles of giant débris covered with lichens and a few hardy alpine plants, the very picture of icy desolation. Nothing foreign shows itself at the surface, and without the removal of these large fragments no one would suspect what revelations have been awaiting their present development. I am able now to say that *decisive evidence exists to show that the glacial ice moved over the top of Mt. Washington.*

The first suggestion of this novel proposition came to me the last day of July, 1875, from an examination of the somewhat rounded stones of small size, lying along the carriage road upon the northeast side of the mountain, about two hundred and fifty

feet below the summit. I stumbled upon two boulders of granitic gneiss foreign to the mountain, one nearly ten and the other six inches long. This raised the altitude at which transported materials existed to nearly 6,100 feet. Observation showed that these boulders came invariably from the earth underlying the conspicuous angular débris common all over the peak above the line of trees. In repairing the road the workmen usually dug beneath the surface blocks before obtaining a material suitable for their purposes, and there always seemed to be a plenty of it. This earth proves to be the ordinary *ground-moraine* of modern glacialists, full of the worn angular and roundish stones which have been fashioned peculiarly by being shoved along. Large boulders are not common in it, though abundant elsewhere. These stones are usually of the same mica-schist and gneissic rocks that compose the adjacent ledges ; and this kind of ledge extends to Israel's River, five or six miles distant from the top of Mt. Washington in a northwesterly direction. Were these deposits situated in the lowlands, they would be pronounced at first sight by any one, to be the common drift heaps of the neighborhood. I did not discover satisfactory evidences of striation upon the few stones picked up near the two boulders of granite just mentioned, but they possess the characteristic shapes of those that are covered with scratches elsewhere. Some are pointed at both ends, being either flattened or round along the middle. Others are squarish or trapezoidal with rounded corners. Many resemble perfectly the shapes figured by Geikie in his recent work on the *Great Ice Age;* and in fact they are of the constantly occurring forms familiar to all glacialists. The rock is quite soft, and that fact may explain the absence of striation.

The question naturally arose as I lifted up these stones, are these the shapes resulting from the cleavage of ledges by frost? No, it could not be, some agency of transportation other than the falling down a slope has worn off the edges, smoothed their surfaces and mixed them with earth. The glacier ice must have transported them, though they cannot have travelled more than five or six miles, or the limit of the extent of this kind of rock. If this were so, then the whole of Mt. Washington was covered by the glacier ice. Thus I reasoned with myself, and began to look further. Remembering that these glaciated stones came from below the surface I sought for localities where the lower earth had

been excavated. The first case examined was the foundation of the Mt. Washington Hotel. In laying the foundations of this edifice—nearly two hundred feet long—the angular débris was first taken up and placed in the cellar walls. When this had been used up the workmen reached the same moraine-mass which occurs below, along the carriage road. Some of the earth was sandy and went into the composition of the mortar used on the walls. There was scarcely any ledge requiring removal. I examined such of the stones as remained in the cellar, as well as possible with a dim lantern, and found everything in agreement with the character of the materials seen two hundred and fifty feet lower along the carriage road. The stones assumed the ordinary glaciated shapes, but I did not discover any material foreign to the mountain. One of the quartz fragments seemed to show traces of smoothing or incipient striation.

Next I examined the excavations made for the road between the house and stables, and obtained several small boulders, four or five inches long, corresponding in mineral structure with the ledges in Randolph and Jefferson, twelve or fifteen miles away. The general color of the rock is so like that of the mountain that one would not perceive the difference between them without close inspection. The mica is arranged differently in it, the white parts are more abundant though in fine grains, and the rock is evidently the same with the upper member of what I call the "Bethlehem Gneiss" in the New Hampshire Reports. The highest point at which these stones of foreign origin were obtainable, may be twenty or twenty-five feet below the very pinnacle of the mountain. Hence it is fair to conclude that every part has been covered by the glacial ice. The glaciated stones, composed of the same material with that of the mountain, are common all along this road to the stables and elsewhere in excavations over the summit.

Being unexpectedly called away I had not time to search carefully for striæ upon the ledges. Just beyond the Signal Station dwelling I found a flat ledge sloping a little northwesterly and precipitously on the southeast. Atmospheric agencies have marred the surface so much that no striæ are visible, even if they ever existed. I had proposed to scrutinize every harder projection of quartz with a lens, as this course sometimes reveals striation where other inspection is unavailing. Were this ledge situated near the Lake of the Clouds, where embossment is common, I should

point it out unhesitatingly as an example of ice-sculpture, though much degraded by weathering. The shape agrees with that of thousands of glaciated ledges in other parts of the state. Other ledges on the mountain farther north resemble this one. Inasmuch as the transportation of materials is clearly proved by the presence of the Jefferson rock upon the summit a few rods away, it will not be unreasonable to believe that this apparent embossment is real. The altitude of the ledge is the same with that of the site of the travelled stones.

The disposition of the large blocks upon the summit is noteworthy. Several acres of surface are covered by them far away from visible ledges. As you approach a ledge it is easy to see what fragments have been separated by frost action, as the projections match the indentations, and a very few feet of distance represents the extreme amount of removal, save on a steep slope. Since the surface covered by the large angular blocks is quite extensive and comparatively level, it is fair to conclude that the transportation has been effected by the glacier and not by frost. The latter agency, however, has very industriously operated upon both ledges and boulders in post-glacial times, so that the shattered ledges, their fragments and the fractured boulders, form a continuous field of angular débris over the whole upper cone of the mountain.

From these facts the following conclusions seem legitimate:

1. The glacial ice completely covered and passed over the summit of Mt. Washington in a southeasterly direction.

2. It brought along a large amount of moraine rubbish and glaciated stones which were disposed in various hollows and convenient locations about the mountain, in the same way that the ground-moraine is distributed in the lowlands.

3. Subsequently an immense number of large blocks of stone taken from the northern slope of the mountains were transported to the summit (as well as beyond), and left overlying the finer earth-débris of a previous transport.

4. Frost and gravity have been acting upon the boulders thus transported and the ledges, so that every large block has been split up into smaller ones, and this angular débris entirely conceals from view the previously formed moraine, and the summit is apparently destitute of soil.

FORMATION OF GEYSERITE PEBBLES IN POOLS ADJACENT TO THE GEYSERS OF THE YELLOWSTONE PARK. By THEO. B. COMSTOCK, of Ithaca, N. Y.

ABSTRACT.

IF the bowl of a geyser be not so large that the ejected water will fall wholly within the pool, there are always left about the rim peculiar excrescences, varying with the height and character of the ejected mass of water. These prominences are produced by evaporation, or, more properly, crystallization from the hot siliceous solution thrown out during an eruption, and they are thus gradually built up by accretion. Frequently loose polished pebbles of geyserite are found in shallow pools adjacent to the larger geysers. Hayden and others have supposed that these are formed by accretion similarly to the prominences just mentioned. Careful examination, however, shows that they are, in reality, broken prominences worn down by attrition in the pools when the water falls upon them during an eruption. This is proven by the fact that the layers exposed in a cross section are not usually continuous, but they have become more or less truncated. The pebbles are commonly lozenge-shaped or polyhedral.

REMARKS ON THE HOT SPRINGS AND GEYSERS AND OTHER TOPICS ILLUSTRATING THE SCIENTIFIC VALUE OF THE YELLOWSTONE PARK. By THEO B. COMSTOCK, of Ithaca, N. Y.

ABSTRACT.

THERE are no geysers of consequence on the Yellowstone River, so far as known. The geysers of the Yellowstone Park are on the Madison River and tributaries, and on certain of the sources of Snake River. The most remarkable feature of the thermal springs in this region, is the wonderful variety of the deposits, resulting from very slight changes in temperature, composition or other circumstances connected with the geological structure or physical geography of the district, giving rise to salses, solfataras, fumaroles, geysers, or mere clear springs of hot water, periodically

agitated, quiescent or throbbing, eruptive, bubbling, puffing or hissing, according to the character of the surface soil and the size and shape of the external orifices. The products are even more variable, consisting of every conceivable grade of admixture of the ingredients which go to make up the trachytes, basalts, rhyolites, propylites and andesites of the great lava flood of the West, mingled with the materials of the more recent superficial beds. It is scarcely beyond the truth to state that among the thousands of hot springs in this section, there is not one which does not possess some feature of interest peculiar to itself, and when it is remembered that the deposits from ancient thermal springs are enormous in proportion to those now forming, it will be conceded that the phenomena connected with them, the history of their formation, and the successive steps in the gradual dying out of the volcanic fires, can be studied nowhere in the world to better advantage than in the Yellowstone National Park. The great "bath-tub" formation on Gardiner's River, is alone worthy the endurance of much hardship and privation on the part of the chemist or physicist, in order to witness processes of combination and dissolution not elsewhere to be observed in nature. Each geyser may be known as truly by the character of its mechanical deposits, as by any peculiarity of its chimney or by the size and shape of its bowl. Iron, sulphur, calcium, silica, magnesium, and aluminium, enter into the composition of crystals of the most diverse forms and colors, many of them hitherto unknown. Organic matter constitutes the basis of interesting masses within the pools and streams, and carbonic acid, both free and combined, plays an important part in the deposition. Gelatinous substances of uncertain origin assume structures of the most delicate and indescribable shapes, with colors of almost every hue. But this small area is but a slight portion of the whole, and each group of springs is in itself a field for a lifetime of study. The National Park is forty-five by fifty-five miles in area, and it contains very many groups of these springs, including a large number of geysers. It is also a region of rare scientific interest for other reasons, prominent among which is the fact that it is in a measure an isolated tract, with arms, in the shape of river valleys, reaching out in all directions. Thus there are found here representatives of animals living in widely separated districts. The reports show that forms from British America, New Mexico, California, Oregon and other sec-

tions are here brought together, probably as estrays which have worked up along the valleys of the great rivers of North America which here originate. Again, there are in this section remnants of animal forms, very valuable both from practical and scientific stand-points, which are rapidly being exterminated at the hand of improvident man, savage and civilized (!). Of these may be mentioned the bison, the American elk, prong-horn antelope, deer, beaver, mountain sheep and Rocky Mountain antelope. More important, scientifically, are the wolverine, grizzly bear, moose, and others (to which I have referred in the "American Naturalist," March and April, 1874) on account of their affinities with ancient types.

To sum up, then, there are opportunities here for the solution of certain problems in physics and physical geology, which are afforded nowhere else. The present source of the heat and of the water supply in the hot springs and geysers is unknown, and the cause of their periodic action is equally dark. The origin and history of the volcanic outflows is a subject of absorbing interest also. There are many animals in imminent danger of extinetion, which thrive in this section, and there is need of much better protection for the rarities of all kinds abounding there. Congress has provided for a superintendent (Ex-Governor Langford of Montana) without any arrangement by which he may be compensated for his services.

To me, it seems a matter of great moment to science, that we are neglecting the opportunity to observe and record the rapidly waning phenomena of this region, and there is every reason to believe that a winter spent among the geysers would well repay the student of thermo-dynamics. In view of all this, I feel the urgent need of some action by which the Yellowstone Park reservation may be made a conservatory of the vast amount of physical and biological material now being wasted, so to speak, in the West. I would, therefore, respectfully suggest that the American Association take into consideration the propriety of bringing this subject to the attention of the General Government, that the Yellowstone National Park may become not only a "pleasuring-ground," but also a physical laboratory and a natural zoological garden for the benefit of students. Further argument is, I trust, unnecessary. The facts are recorded in all the reports which have come from the region in question.

On Some New Specimens of Fossil Protozoa from Canada. By J. W. Dawson, of Montreal.

1. EOZOON CANADENSE.

The author had recently reëxamined the locality at Petite Nation, on the Ottawa, one of the most productive in good specimens of this ancient fossil, with reference to the settlement of some questions as to its mode of occurrence. The following points were illustrated by the facts obtained.

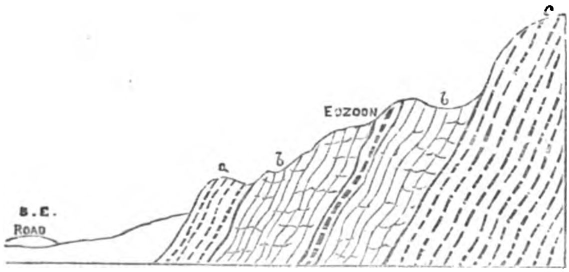


Fig. 1. Attitude of Limestone at St. Pierre. (*a.*) Gneiss band in the Limestone. (*b.*) Limestone with Eozoon. (*c.*) Diorite and Gneiss.

1. The regular arrangement of entire specimens of Eozoon and also of layers of fragments in the beds of limestone. The limestone of Petite Nation is a very thick bed, belonging to the Grenville band of Sir William Logan. It rests upon stratified gneiss and diorite, and has intercalated beds of gneissose rock. The entire specimens of Eozoon, showing rounded forms and distinct laminated structure, occur only in certain layers; but others are filled with broken angular fragments of the fossil. The specimens are usually mineralized with serpentine, but beds occur with nodules of serpentine destitute of the structure of Eozoon, and in certain dolomitic layers there are abundance of fragments of Eozoon without serpentine. The veins of chrysotile or fibrous serpentine are of origin subsequent to the stratification, and cross the beds, and also the masses of Eozoon, without regard to their structure. The mode of occurrence of Eozoon, is therefore, precisely similar to that of fossil corals and Stromatoporæ in the Silurian rocks.

2. The occurrence of other forms of organic origin along with Eozoon. In the layers holding fragmental Eozoon there are numer-

ous minute groups of rounded cells aggregated together, and resembling in form the Globigerinæ of the chalk and of the modern ocean, though having the structure of the cell-wall finely porous like that of Eozoon. For these, in a paper recently presented to the Geological Society of London, he had proposed the name of *Archæospherinæ.* Whether they are distinct organisms, or merely germs or buds thrown off from the surface of Eozoon he was unable to decide. He had also found certain larger masses of an acervuline cellular organism, differing in structure from the typical Eozoon, and a more finely laminated variety or species, with comparatively little development of supplemental skeleton.

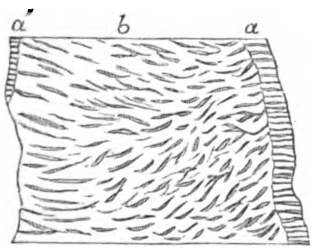


Fig. 2. Portion of a Lamina of Eozoon from a very thin slide, showing proper wall at *a a'*, and intermediate skeleton with canals at *b*.

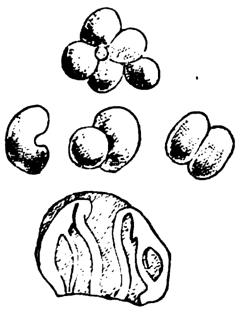


Fig. 3. Archæospherinæ.

3. The stromatoporoid appearance of the weathered masses of Eozoon. In the limestone of Petite Nation, weathered specimens from an inch to a foot in diameter project from the surface of the limestone, showing their lamination, and so precisely resembling in form and mode of occurrence the Silurian Stromatoporæ that it would be impossible to distinguish them except by microscopic examination.

4. The frequent infiltration of the canal system with dolomite as well as serpentine. The frequency of this at Petite Nation has not received so much attention as it deserves. In many specimens the minute ramifications of the canals are filled with crystalline dolomite, while the larger trunks of the same canals are filled with serpentine. In other cases the whole extent of the canals is occupied with dolomite. This mineral is liable to be dissolved away in decalcified specimens, and in slices its similarity to the calcite may cause it to escape observation.

All these points serve to elucidate the animal nature of Eozoon, and to place this in a more clear light, in so far as the mode of occurrence of the fossil in the containing beds is concerned. They may also serve to correct misapprehensions as to the supposed extension of the forms in perfectly indefinite masses, constituting continuously the whole material of certain limestones. They also illustrate the difference between the laminated specimens of the fossil, showing their general form and arrangement of parts, and the collections of fragments which occur in certain beds, often without any perfect fossils, just as comminuted corals occur in the Trenton limestone. It had also been clearly ascertained that the veins of fibrous serpentine had no connection with the fossil, and are of subsequent origin, filling cracks which traverse the specimens often without any regard to their lamination. The details of these observations will be illustrated in a work by the author now in the press.[1]

2. CRETACEOUS FORAMINIFERA, ETC., FROM THE WEST.

The Imperial and Canadian governments wisely decided to commission a geologist in connection with the survey of the boundary line along the forty-ninth parallel, from the Lake of the Woods to the Rocky Mountains, which has just been completed. This work was entrusted to Mr. G. M. Dawson, Associate of the School of Mines, London, whose Report is in the Press.[2] In the prosecution of this survey, it was made the main object to secure as perfect a line of section as possible, across the newer formations intervening between the Laurentian and Huronian of the Lake of the Woods, and the Palæozoic rocks of the Rocky Mountain Range, and to correlate this with the work of the United States Surveys on the south and of the Canadian Surveys on the north. This had been pretty effectually done, for this long line of 800 miles along the boundary between the Western States and Territories and the Dominion of Canada. Attention had also been given to the vexed questions relating to the arrangement of the cretaceous

[1] Specimens collected since the paper was read show that the acervuline surface of Eozoon was capable of producing groups of loose cells precisely similar to the Archæospherinæ; and recent discoveries in the Laurentian of Canada have established a probability that all or nearly all the localities of Eozoon occur nearly on one horizon in the Lower Laurentian, thus tending to make this the characteristic fossil of one zone in this great series of rocks. Details of these facts will shortly be published.

[2] Published Sept. 5, 1875, pp. 379, with maps and plates.

and lignite-bearing formations, and to the distribution of débris from the Laurentian axis and the Rocky Mountains in the pleistocene period, and the formation of the vast mounds of boulder-clay known as the Missouri Coteau, and its outlying ridges and hills.

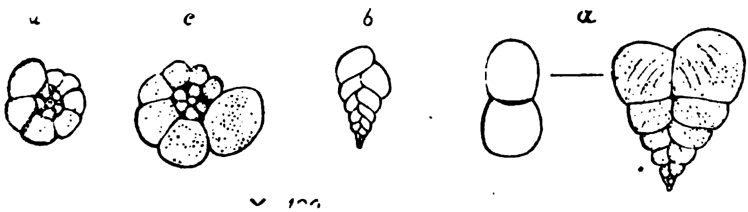


Fig. 4. Foraminifera from the Cretaceous of Manitoba. (*a.*) Textularia globulosa (*b.*) T. pygmæa. (*c.*) Discorbina globularis. (*d.*) Planorbulina Ariminensis.

The only point to which it is desired to refer in detail here, is the recognition of the cretaceous foraminiferal limestone of Hayden's No. 3, or Niobrara group far north in the British territory,

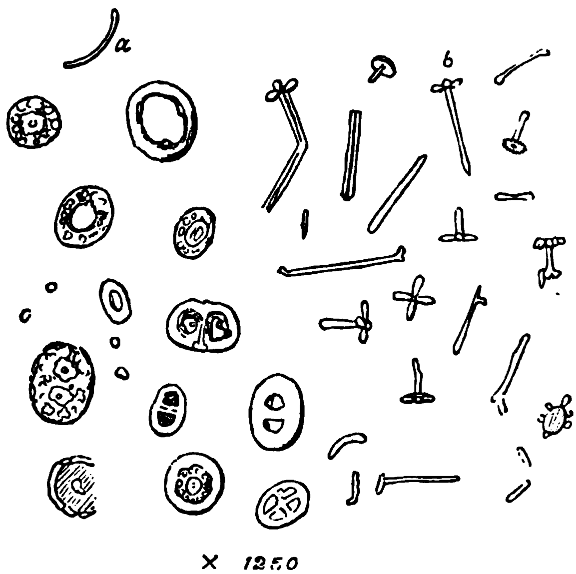


Fig. 5. Various forms of Coccoliths (*a*) and Rhabdoliths (*b*) from the Cretaceous of Manitoba.

and some additional facts as to the organisms contained in it. This formation occurs in Pembina Mountain 400 miles to the north

of localities where it was first described in Nebraska, and the exploring parties of the Canadian Survey have recently found it still farther to the north-westward at Lake Winnepegosis. The specimens of this limestone are composed in part of shells of *Ostrea congesta* and *Inocerami*, included in a chalky or stony mass, which consists largely of Foraminifera, Coccoliths and Rhabdoliths. The Foraminifera, most of which have already been catalogued by Ehrenberg, from the Nebraska and other localities, are of species and varietal forms extensively distributed in the chalk of Europe and in the modern ocean, for the most part characteristic of depths ranging from fifty to one hundred fathoms. The Coccoliths, which seem not to have been previously recognized in the cretaceous of America, are precisely similar to those of the European chalk and of the modern oceanic mud, and in some parts of the bed exist in vast abundance. They are associated with the peculiar rod-like bodies named by Oscar Schmidt Rhabdoliths, which have not previously been recognized as fossils. This old cretaceous sea-bottom thus forms an important horizon on the western plains, indicating oceanic conditions, from which the overlying beds show a transition to the swamps and fresh-water lakes which overspread the same area in the succeeding periods of the upper cretaceous and lignite tertiary.

The following remarks as to the fossils are from the Report above referred to.

"180. These larger shells are imbedded in a soft, whitish, earthy matrix, which is found, when microscopically examined, to consist almost entirely of the more or less perfect remains of Foraminifera, Coccoliths and allied organisms; together with the small irregular prisms arising from the disintegration of Inocerami. The Foraminifera represented are: *Textularia gibbosa* D'Orb., var. *globulosa* Ehr. *Textularia agglutinans*, var. *pygmæa* D'Orb. *Planorbulina globulosa* Ehr. *Planorbulina farcta*, var. *ariminensis* D'Orb. *Globigerinæ* referable to *G. cretacea*, also occur though not abundantly. All these I have also identified in specimens of the Niobrara limestone from Eau qui Court in Nebraska. The first named species was found by Ehrenberg in the Brighton and Gravesend chalk, being one of the commonest forms in the latter. It also occurs in the Meudon chalk of France, and is still living in the Mediterranean and elsewhere, at depths of from fifty to one hundred fathoms. The second textularine form is closely allied

to, if not identical with, one found in the English chalk, and is common at the present day in the North Atlantic and elsewhere; becoming, however, rare and small at great depths, and apparently most at home at a depth of about ninety fathoms in the latitude of England. *Planorbulina globulosa* is common in the modern ocean, and in the North Atlantic is best developed from the shore-line down to fifty or seventy fathoms. The specimens from Manitoba resemble those from the greater depths in being considerably flattened. The second Rotaline form is abundant in the English chalk, in that of Möen, Denmark, and doubtless elsewhere; and is also found in Tertiary and recent deposits."

"181. The general facies of the foraminiferal fauna of these Cretaceous rocks of Manitoba, as well as those of like age in Nebraska, singularly resembles that of the English chalk. Both abound in textularine and rotaline forms of similar types; the more abundant in both, being the form with globose chambers, and each having its rarer analogue, with chambers flattened and more delicate."

"182. The finer part of the softer portions of the rock, is composed almost entirely of the extremely minute bodies, which are included under the general names — *Coccoliths* and *Rhabdoliths.* These are now known to belong to minute pelagic vegetable organisms. Coccoliths are abundant in most modern oceanic deposits, and have long been known to occur in the chalk of England and elsewhere, but do not appear to have been previously observed in the Cretaceous rocks of America. The allied Rhabdoliths were discovered by Dr. O. Schmidt in 1872, in the Adriatic Sea; but I do not know that they have heretofore been found in the fossil state. These very minute bodies are well preserved in the limestone from Boyne River, and run through the same set of forms as those described by Dr. Schmidt."

"183. The limestone, where it occurs on the Boyne River, appears to be interleaved with beds of soft clay; but the accounts I have received, are not sufficiently precise to enable any definite conclusions as to its thickness or extent, to be arrived at. Its occurrence at this one locality, enables the outcrop of the Niobrara Division — or highest bed of the Lower Cretaceous series — to be defined at a point nearly four hundred miles further north than it has previously been known, and fixes the position of a well-marked horizon in the Cretaceous rocks of the Northwest."

NOTICE OF NEW AND INTERESTING COAL PLANTS FROM OHIO. By E. B. ANDREWS, of Lancaster, Ohio.

Two or three years ago I noticed in a ditch by the roadside in the western part of Perry County, Ohio, a thin layer of bituminous shale. Its stratigraphical position is near the base of the Ohio coal-measures, perhaps thirty feet above the Maxville limestone, the equivalent of the Chester limestone of Illinois. A few strokes of the hammer revealed a fragment of a coal-plant entirely new to me. This led to subsequent visits to the location, and the discovery of a large number of new forms of ancient vegetation. At the bottom of the layer we find less than an inch of a very peculiar band of vegetable origin of brown color, soft like rotten wood, without lamination, and filled with fragments of a minute form of plant resembling the small branchlets of *Calamites*. In it are scales of a fish, thought by Dr. Newberry to be entirely new to science, and a small *Lingula*, perhaps too indistinct for specific determination. Above this curious, half solidified, brown band we find an inch of highly bituminous cannel-shale presenting a satin surface in its fracture. This shale contains a few plants, the most numerous form being leaves of *Lepidodendron*. This shale passes upward into an ordinary bituminous shale, in the lower two inches of which nearly all the plants are found. We have here the evidence of a marsh in which there first was accumulated upon a micaceous sand the minute Calamitoid plants. These were buried by a highly bituminous sediment, into which fell innumerable leaves of *Lepidodendra*, long, straight leaves often a foot in length. Then came in a luxuriant vegetation of ferns, etc., which are now buried in the higher shale.

So far as I know, this marsh must have been of very limited extent, for I have found no trace of it in the same geological horizon elsewhere, in the neighborhood. The shale is so deeply buried on its outcrop, that, so far, only a few square yards have been uncovered and examined.

In this little marsh grew plants of well-marked Devonian types, and others of a type generally found in formations more recent than the coal-measures. Besides these, we find many coal-measures forms, but, with scarcely an exception, they are of new species.

Of the Devonian forms, one is a new species of *Archæopteris* Dawson (*Palæopteris* Schimper). The *A. Jacksoni* Dawson,

from the Devonian of New Brunswick and Maine, may be regarded as a typical form of this genus. The new Ohio species I have called *A. stricta*. It is a fern of great beauty, smaller and more delicate than *A. Jacksoni*. The pinnæ are alternate, somewhat closely set, growing out of the rachis at an angle of 70° to 75°, rarely as small as 45°. The pinnules are alternate, oblanceolate, obtuse, decurring on the narrow rachis, disconnected to the base, with a strong nerve dividing near the base into three to five branches, which themselves fork once or twice before reaching the margin. Prof. Fontaine reports the finding of *A. Jacksoni* in his Conglomerate coal-series on New River, W. Va., over a coal-seam perhaps 500 feet above the base of the coal-measures. This is more than 1500 feet lower in the series of the Alleghany coal-measures than my Ohio form. He also finds the same *A. Jacksoni* in Vespertine slate in Greenbrier County.

Another Devonian genus found in the little marsh in Perry County, is the *Megalopteris* Dawson. The only species of this genus before known was first found by Prof. Hartt in New Brunswick, and described by him as *Neuropteris Dawsoni*. Prof. Fontaine has recently found the same, or a very closely allied species, in the lower coal-measures on New River, where he found the *A. Jacksoni*. Of this genus I have found four new species, which I have called *Megalopteris Harttii*, *M. ovata*, *M. lata* and *M. minima*. The first three of these are closely allied to *M. Dawsoni* Hartt. The last, *M. minima* has much the appearance of an *Alethopteris*, but it is undoubtedly a true *Megalopteris*. Some of the new species were ferns of great beauty and of large size. This genus has special interest and value because found in our coal-measures in Ohio, only about 700 feet below the great Pittsburgh seam of coal. The West Virginia species, found by Prof. Fontaine, came from a horizon more than 500 feet lower. But from this horizon, which is low in the original geosynclinal trough or depression in West Virginia, it is a long way down to the Devonian formation, which, in New Brunswick, yielded to the hammer of Prof. Hartt his *Megalopteris Dawsoni*. The new species from Ohio are directly separated from any Ohio Devonian rocks by, first, a few feet of coal-measures, second, by the Lower Carboniferous Maxville limestone the equivalent and representative of the Chester limestone of Illinois, there 600 to 800 feet thick, and third, by the Waverly sandstone, over 600 feet in thickness. These facts are of

interest as showing the distribution in the great time series of this genus of ferns. If, however, we should apply the republican rule of majorities to science, the finding of several species in the coal-measures, and but one in the Devonian, should determine this to be a true coal-measures form. Then the Devonian species becomes the prophetic one.

Growing in one little marsh with the *Archæopteris* and the *Megalopteris* is a new and very beautiful fern of a new genus closely allied to a more recent type, belonging to the order of the *Tæniopterideæ.* No form of this order has hitherto been found so low in the coal-measures. *Tæniopteris multinervis* Weiss, belongs to the upper coal-measures and Permian of Europe, but most forms of this order are still more recent. The only American representatives of this group, so far as I know, are *T. magnifolia* Rogers, from the Triassic coal field near Richmond, Va., and, with other plants, used by Prof. W. B. Rogers to determine the geological age of that field; and *T. vittata* Brongt. reported by President Hitchcock from the Red Sandstone of the Connecticut Valley.

The new Ohio genus I have called *Orthogoniopteris* from its rectangular nervation. The following is a description of the genus: *Orthogoniopteris, nov. gen. Frond simply pinnate. Pinnæ alternate, lanceolate or oblong, linear, rounded or tapering to an acute point, entire or undulate, enlarged and decurrent on lower side, rounded on the upper to the medial nerve and joining it a little above the point of its attachment to the rachis. Medial nerve prominent, thick, and ascending to the apex. Nervules forking once very near the middle nerve, extending at right angles to it and curving upward slightly at the margin, very fine, numerous and uniform.* Two species have been found, *O. clara* and *O. Gilberti.* This genus is allied to *Tæniopteris* Bront., to *Angiopteridium* Sch., and to *Neriopteris* Newb. The nervation is similar to *Tæniopteris*, but *Tæniopteris* has a simple frond while this is pinnate. In *Angiopteridium* the frond is pinnate, and the pinnæ are cordate or rounded with marginal fructification. In Dr. Newberry's new genus *Neriopteris* the pinnæ are similarly cordate, with acute angled nervation and with a supposed marginal fructification.

In this new genus the pinnæ are decurrent below and rounded and free above, with rectangular nervation. In the decurrent base of the leaflets it is allied to the larger forms of *Alethopteris*, but it doubtless belongs to the order of *Tæniopterideæ.*

Besides this new genus there is a new Alethopteris greatly resembling in form and nervation *A. tæniopteroides* Bunbury, from the coal-field of Cape Breton, but specifically different. Another fragment of a supposed *Alethopteris* also possesses a nervation much like the *Tæniopterideæ*. If a true *Alethopteris* it is of longer leaf than any other species of this genus except *A. ingens* Dawson, but is somewhat different in nervation.

There is another new *Alethopteris*, which I have called *A. Holdeni*, of great size and beauty, belonging to the section of the genus which may be represented by *A. Serlii*, and is doubtless allied to Dr. Newberry's new species *A. macrophylla*. The essential characters which separate it are, first, the great length of the frond which measures at least fifty centimeters; second, its lanceolate or rather oblanceolate form, the leaflets decreasing in length toward the base; third, the linear, taper-pointed form of the leaflets, comparatively long and narrow; and fourth, the always simple division of the frond. It is possible that we have in these various species of *Alethopteris* and in closely allied ones, a group which should be detached and formed into a new genus.

This group passes in resemblance into the type of the *Tæniopterideæ* on the one hand, and through the *Megalopteris* (the *M. minima* having decidedly the look of an *Alethopteris*) into the distinct *Neuropteris* type on the other. These resemblances are of great interest, and serve to bring the Devonian and Mesozoic flora into greater harmony.

Besides the forms already mentioned there grew in our little Ohio marsh, a new *Asterophyllites*, a new and beautiful *Hymenophyllites*, a new and pretty *Eremopteris*, two species of *Lepidodendron;* one allied to *L. tetragonum* Sternb., found by Dr. Dawson in the Lower Carboniferous of Canada; two species of *Cordaites*, a new and large *Cardiocarpon*, a large and beautiful cone of somewhat doubtful affinities, besides several other forms not yet determined.

The most important plants in the collection are figured and will be published in the next volume of the Ohio Geological Reports.

NEW AND INTERESTING INSECTS FROM THE CARBONIFEROUS OF CAPE BRETON. By SAMUEL H. SCUDDER, of Cambridge, Mass.

DR. J. W. DAWSON has placed in my hands a piece of carboniferous shale from Cape Breton, containing remains of several insects. The best preserved and most interesting is the abdomen of a larval Dragon-fly. Odonata, both mature and in their earlier stages, have previously been found in the Jurassic beds of Solenhofen; wings and fragments of other parts have also been found in the English Lias, and a specimen, which may be an odonate larva, has been figured by Brodie from the Oxford Clay. No true Odonata, however, have been discovered so low as the carboniferous formation, unless the obscure fossil, thought by Goldenberg to be possibly a Termes,[1] may properly be referred to this group.

In the last edition of Dr. Dawson's Acadian Geology, however, I have, described (p. 387) the wing of an insect, *Haplophlebium Barnesii*, which certainly bears some striking resemblances to the Odonata, and of which it is not impossible that the present fossil may be the larva.

The abdomen of the specimen (fig. 1) is nearly perfect, and presents a ventral aspect, portions of the flanks of the body may

Fig. 1.

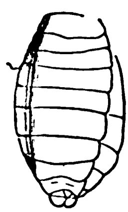


Fig. 2.

be seen on either side; upon the left side in direct continuity with the ventral segments and very distinctly, especially since this region is darker colored than the other parts of the abdomen. The limitation between the ventral and pleural portions is sharply defined on this side by slight ridges, showing that in life these

[1] See Dunker and Meyer's Palæontographica, iv, pl. vi. fig. 8. Subsequently (Vorw. Faun. Saarb. 12) Goldenberg refers this definitely to the Termitina, under the name *Termes* (*Calotermes*) *Hageni*.

parts were abruptly limited, while the margination of the extreme border of the fossil shows that, as in living odonate larvæ, the dorsal was again separated from the pleural region of the abdomen by a distinct bend. The abdomen is elongate-ovate, devoid of any armature, composed of nine segments, the ninth obscure and bearing a pair at least of rounded lobate pads of considerable size, but not as in recent Odonata, pointed at the tip. The second to the fifth segments are shorter than the others; the posterior edge of all the segments is straight, excepting that of the seventh, which is gently convex, and that of the eighth, which is strongly and roundly excised; that of the ninth appears also to be regularly concave. The entire length of the abdomen is 13.5^{mm}, and the width of the fifth or broadest segment 6.5^{mm}, counting only the ventral portion; the appendages are 1^{mm} long.

It is impossible to say to which group of Odonata the fossil belongs. The Agrionina, are however, unquestionably to be excluded. It seems to be most probably one of the Libellulina, and may be provisionally placed in the old genus Libellula (which formerly contained all the Odonata) and bear the name *Libellula carbonaria*.

Accompanying this interesting fossil is a frond of Alethopteris and two fragments of wings of cockroaches. One of the latter is too insignificant to be worth noticing, but the other is sufficient for determination, and may be called *Blattina sepulta* (fig. 2). It appears to be nearly allied to *B. carbonaria* Germ., but differs from it in some important particulars. It is very imperfect, a portion of the outer border being the only part of the margin which is preserved, but most of the disk of the wing is present; probably the entire wing measured nearly 15^{mm} in length; the fragment that remains is but 6.25^{mm} long and 5^{mm} broad. The anal nervure is no more deeply impressed than the others, rather regularly curved, and itself emits several branching and simple shoots from its posterior border; the anal field (and apparently also the middle field) is covered with very frequent cross-nervules, not represented in the figure; the branches of the middle field appear to be not very closely crowded, distinctly less so than those of the costal field.

The fossils were obtained at Cassett's Pit, near Sydney, Cape Breton, by Mr. A. J. Hill, C. E., from "near the horizon of the Millstone Grit," as I am informed by Principal Dawson.

OBSERVATIONS ON THE MEMBRAL MUSCULATION OF SIMIA SATYRUS (ORANG) AND THE COMPARATIVE MYOLOGY OF MAN AND THE APES. By W. S. BARNARD, of Canton, Ill.

CONSIDERING the many dissections of *S. satyrus*, made by eminent anatomists, our knowledge of its membral muscles and their homology with those of man and the higher apes remains astonishingly incomplete. The muscular system is fundamentally divided into a series of segments or mycomal parts, each of which may be subdivided into fractional parts called muscles. The late attempts of anatomists to point out a general plan in the vertebrate muscular system and to refer each muscle to its natural series, gives myology a fresh interest and importance. This is a kind of work similar to that done by Owen, Gegenbaur, and others, for the morphology of the vertebrate skeleton and its archetype and homologies. Since the osseous and muscular systems are so intimately related, analogous results may be expected. Lately, some of our American anatomists have given further evidences of an antero-posterior symmetry, such as was vaguely hinted at by Oken, (10), and partly pointed out by others. By the great number of so-called antero-posterior homologies, in both the bones and muscles, as pointed out by Wyman (17), Wilder (16), and Coues (3), they are led to maintain that a special as well as a general antero-posterior symmetry exists between the front and hind limbs. Wyman finds proof of this in the ontological development of some vertebrates; furthermore it is corroborated by a great mass of evidence by comparison, and the whole seems to them to imply that antero-posterior symmetry is properly a character of the vertebrate archetype. On this account these would place the limbs in an "antitropic" position for comparison, while Owen and others would place them parallel and pointing backwards in a "syntropic" position. I would adopt neither of these, but compare the limbs in a position extending laterally, at right-angles to the vertebral column and parallel to each other, believing that all appearances of either "syntropic" or "antitropic" symmetry in the limbs are secondarily developed for functional purposes, and we must beware of giving these characters too great morphological value.

Besides attempting to show that a symmetrical relation of "antitropy" can be traced specially between the muscles of the anterior and posterior members, Coues (3), and Wilder (op. cit.) have done something towards establishing a natural classification

of the muscles; the former by grouping them according to the segments or parts on which they insert, and by adopting the subdivisions proposed by the latter, into "short" and "long" muscles respectively, as one or two joints occur between the origin and insertion. I have become convinced that muscles are much more constant as to the relative position of their origins than as to that of their insertions; that the position of the origin has the greater morphological and homological value, and this leads me, contrary to the systems of anatomists generally, to base the main groups of muscles on the groups of origins as limited by the osseous segments and parts on which they exist. Each of these should be subdivided into subordinate groups based on the groups of insertions as limited by the osseous segments or bones similar to the following scheme.

MUSCLES TELEOLOGICALLY OF THE HIND LIMBS.

A.——— *arising from the body.*
- a.—inserting into the pelvic girdle.
- b.—inserting into the femur.
- c.—inserting into the crural bones.

MUSCLES PROPERLY OF THE HIND LIMBS.

A.——— *arising from the femur.*
- a.—inserting into the crural bones; "short."
- b.—inserting into the tarso-metatarsus; "long."
- c.—inserting into the toes; "long."

B.——— *arising from the crural bones.*
- a.—inserting into the tarso-metatarsus.
- b.—inserting into the toes.

C.——— *arising from the tarso-metatarsus.*
- a.—inserting into the toes.

MUSCLES TELEOLOGICALLY OF THE FORE LIMBS.

- a.—inserting on the shoulder girdle.
- b.—inserting on the humerus.
- c.—inserting on the cubitus.

MUSCLES PROPERLY OF THE FORE LIMBS.

A.——— *arising from the humerus.*
- a.—inserting into the cubitus.
- b.—inserting into the carpo-metacarpus.
- c.—inserting into the fingers.

B.——— *arising from the cubitus.*
- a.—inserting on the carpo-metacarpus.
- b.—inserting on the fingers.

C.——— *arising from the carpo-metacarpus.*
- a.—inserting on the fingers.

Those muscles which arise from the body are said to be teleologically of the limbs, because I regard them as mycomal parts of the trunkal series, more or less modified and compounded, especially in their distal parts, to attach on the limbs and make them act in relation to the body. My reasons for this are from comparison and ontology (7). In the development of the limbs, at the time when the muscular tissue has begun to differentiate, the muscular coat of the body, by an outgrowth, projects a short distance into the base of the appendage, from which, however, it seems to be segmented off quite distinctly, except by a slight attachment to the central axis, while the properly membral musculation originates and developes *in situ*. They develop like, and may be compared to, those morphological body muscles, which arise from the internal skeleton and insert on the skin; *e. g.*, the muscles which arise from the ribs of snakes and insert on their abdominal scutes, the *pubo-dorso-cutaneous* and the *coccy-dorso-cutaneous* (Duges) muscles of Amphibia, *musculi patagii* of birds. They insert on the skin but are no part of its musculation; likewise with the body muscles, which insert on the appendages (limbs) but do not morphologically belong to them. By making a proximal estimate of the relative values of characters, I hope to have avoided some very common and deleterious errors. Muscles are generally determined as homologies, by one or more of the following characters, which I have subordinated in accordance with their relative degrees of variability. Those parts which maintain their relative positions most constantly, stand first as having the greatest morphological value. 1. Relative position of the origin. 2. Relative position of the insertion. 3. Relative position of "the line of traction." Most anatomists agree that in determining the homology of a muscle, its relative position seems to be the only character of real, essential value. This is evidently the most valuable when we compare the organs as *wholes*. But a part of an organ may maintain its relative position more constantly than the whole, and that of the various parts of a whole, one may be more constant than another; all the other parts of a muscle may have changed while one remains the same. To determine a muscle by its "line-of-traction" is only to decide from its general relations. The relative position of the origin seems to be the most constant and valuable of all characters by which homologies may be distinguished. The "line-of-traction" suffers all the variations

of both the origin and insertion (its two extremities) as well as others, and consequently it is a third-rate character. Dr. Coues based his classification on the insertions, apparently believing in the general view, that they suffer less mutation than the origins. This I must regard as a mistake, and it also seems inconsistent with the fact that he regards the "line-of-traction" as having more value than either of the attachments. Any person can see that the excessive variability of the insertions on the hand and foot, is so great that the muscles in general cannot be identified by these distal attachments. Pagenstecher (12) noticed this in some of these muscles and gave them better names based on the position of the origin. Thus *flexor longus pollicis proprius* becomes appropriately, *flexor digitorum communis longus fibularis*, since it always arises chiefly from the fibula, but varies (in its distal parts) to act on one or more of the toes; also *flexor longus digitorum* becomes *flexor digitorum communis longus tibialis*, because the position of the origin remains the same, on the tibia, while it inserts variously on the toes. The morphological individuality and homological position of a muscle, is best indicated by its origin, while its physiological individuality and position is more often indicated by the insertion. Our incorrect knowledge of the muscles generally arises from the homologies being not truly traced out, from the fact that the relative values of the homological characters have been not correctly estimated, and that too great importance has been given to the position of the insertion.

A fact of the greatest importance set forth in this paper is that most (and probably all) special, apparently distinct (so-called "proprius") muscles of the fore and hind limbs belong to, and are morphological parts of, certain of the so-called "communis" muscles, from which they have become differentiated off, or isolated by loss of intermediate parts, so as to appear like distinct muscles in many animals, while in others they are still found in their primitive condition, being mere factors of "communis" forms, as is shown in these studies; e. g., *extensor indicis longus proprius* and *extensor medii digiti* are but parts of an *extensor digitorum communis profundus; flexor pollicis longus proprius* is only a part of *flexor digitorum communis profundus; extensor hallucis brevis* is a factor of *extensor digitorum brevis; flexores breves digiti secundi, tertii, quarti, quinti et flexor brevis hallucis superficialis* are parts of *flexor digitorum brevis pedis.* After these conclusions

we may greatly simplify myological nomenclature and introduce correct ideas of the morphology of these specialized muscles, by discarding their names and remembering them under all variations of form and position as being fasiculi of their respective "communis" forms. Finding these "communis" muscles in their typical condition down among the lemuroids, and tracing them upwards step by step through all their degrees of differentiation until we reach their most specialized ("proprius") forms in the higher apes and man, we follow out with proximate exactness the lines of descent of these specialized muscles from their ancestral typical forms, and this, as well as the inheritance of many rudimentary, and other small muscles, may indicate the descent of man, the higher apes and the lemuroids from a common ancestry. Considering its myology we would not reckon the Orang as man's nearest relative among the apes. In this respect the Gorilla and Chimpanzee probably show closer affinities to the human race. Recognizing the wonderfully superior powers of man's brain and the surpassing functional capacity of his other organs, we cannot avoid concluding that as regards man's physiological or spiritual powers he differs in a greater degree from the higher apes, than these do from the lower apes; yet when we observe the close structural resemblance of man to the Gorilla, Chimpanzee and Orang, we feel bound to conclude with Huxley (6) that these are more closely related to man than to the lower apes. This, then, leads us to an important distinction always to be made in expressing this relationship of man to the apes; namely, that *physiologically* and *teleologically* man stands farther from the higher apes than these do from the lower ones of their kind; whereas, *morphologically* the higher apes rank nearer to man than to the lower apes.

In the orang's pelvis the ilium and ischio-pubic arch are very long. The plane of the arch lies in the antero-posterior and dorso-ventral axes. On this the ilium stands at right angles and the anterior margin of its external surface (from which the *entoglutæus* arises) is the part nearest to the trochanter major. This trochanter would be directly under the antero-superior spinous process were the pelvis erected as in man instead of being so greatly inclined to the front. The length of the pelvis and shortness of the femur give great leverage, enabling the muscles surrounding the hip joint to act very powerfully. Because of the

great height of the ilium the muscles arising from it are unusually long, and this, with the shallowness of the acetabulum and erectness of the surgical neck of the femur, allows great freedom of motion and high elevation of the hind limbs. The muscles extending from the ischio-pubic arch to the femur are necessarily short. In homologizing the pelvic muscles of man and the apes, anatomists have been led astray and deceived by the peculiar conformation of the iliac bones. Thus Traill (14) describing in the Orang what he believes to be *glutæus minimus*, says, "its fleshy fibres are most distinct along the sciatic notch (whence it arises); and as it descends towards the *obturator internus* it becomes a thin tendinous expansion . . . . the insertion is into the great trochanter." Here he was mistaken, for this is evidently *pyriformis*, which he has wrongly homologized as *glutæus minimus*. Having done this, there appeared to him no *pyriformis*, and the *true glutæus minimus* seemed to be a new muscle, and he named and described it as such, saying, "The action of this muscle, which appears peculiar to this animal, is to draw the thigh up towards the body; and it seems especially intended to assist in climbing. On this account we propose to name it the *scandens*, or *musculus scansorius;* and we are disposed to regard it as one of the principal peculiarities in *Simia satyrus*." Singularly this remarkable blunder by Traill has never been discovered, but, since his time, seems to have led astray all other anatomists of the Orang, who, thinking themselves obliged to find this new muscle, the so-called *scansorius*, a supposed great peculiarity of the higher apes, distinguishing them essentially from man and the lower apes, have seriously magnified his mistakes and failed to homologize the *glutei* correctly. Owen (11) noticed it in the Orang as *invertor femoris*. Wilder (16*b*) describes it in the Chimpanzee as *scansorius*. Bischoff (1) also regards it as a peculiarity of the higher apes, and uses it as a weapon against Huxley's statement, that the structural difference between the higher and lower apes is greater than that between the higher apes and man, as follows: "Very remarkably there is found, just with two of the anthropoids, an accessory buttock-muscle, which does not exist, either with man or the lower apes, which Traill first observed in the chimpanzee and named *M. scansorius* . . . . As regards *scansorius* it must be said that the orang and chimpanzee are more unlike man than the lower apes." ("Sehr bemerkens-

werther weise findet sich gerade bei zweien der Anthropoiden ein accessorischer Gesaess-Muskel welcher sowohl dem Menschen als den niederen Affen fehlt, welchen Traill zuerst bei dem Chimpanzee beobachtete und M. scansorius nannte . . . .
Ruecksichtlich des Scansorius aber muss man sagen, dass der Orang und Chimpanzee dem menschen unæhnlicher sind als die niederen Affen.") Humphrey has homologized these muscles correctly in the Chimpanzee, so that his observations do not disagree with mine; in the "Journal of Anatomy and Physiology, Vol. I, p. 254 and 265, respectively, in some notes on the Chimpanzee he says, "I did not discover any distinct scansorius" . . . .
"The other buttock muscles were as in man." The absence of *pyriformis*, the great misplacement of *glutæus minimus* and the discovery of a new muscle, *scansorius* of Traill, Bischoff and others, and *invertor femoris* of Owen, alleged as great peculiarities of the higher apes do not, and never did, exist, either in the Chimpanzee or the Orang or any other ape. These errors were curiously aggravated by Dr. Coues, in his myology of *Didelphys virginiana* (Opossum). He rightly found the *pyriformis* and *entoglutæus* both present, and then finding also another muscle passing from the ilium to the upper part of the femur concluded too hastily that it must be the *scansorius* of Traill. To this muscle he applied the name *ilio femoralis*, for what reason does not appear, since he cites *scansorius* (Traill) and *invertor femoris* (Owen) as homologies. But it so happens that what he called *ilio-femoralis* in the Opposum, is a rudimentary muscle, which, as will be seen, is found in the apes also; it exists in the Orang, and I describe it farther on as *ilio-femoralis subrectus*.

The muscles will now be considered *seriatim* according to the order of arrangement adopted in the classification as presented above.

MUSCLES TELEOLOGICALLY OF THE HIND LIMBS.

A.———*arising from the body.*

a.—inserting on the pelvic girdle.

QUADRATUS LUMBORUM and PSOAS ANTICUS (*psoas parvus*) are not essentially peculiar in the Orang; but in most of the lemuroids (9) *q. lumborum* is closely related to *subiliacus* (iliacus internus) and sends one of its tendons to the crest of the ilium, while the anterior *psoas* is generally larger than the posterior,

hence I have altered their names. The anterior one is the largest in the Chimpanzee and in the Lemuroidea (9), except in *Galago crassicaudatus*. It arises from the bodies of the last dorsal and three lumbar vertebræ in *Lemur catta*, *Cheiromys* and *Tarsius*, but in the latter it bifurcates distally and is pierced by *p. posticus* and *subiliacus*. In the others it arises only from the lumbar vertebræ; in *Nycticebus* from the 2. and 3.; from the 2., 3., and 4. in *L. xanthomystax*; from the 3., 4., and 5. in *G. crassicaudatus* (9).

b.—inserting on the femur.

Psoas posticus (*p. magnus; see p. anticus*) arises as in man and the Chimpanzee, but differs from man's in being very long and blending with *subiliacus*. These two muscles are not at all distinct, but seem to form one, the "*flexor femoris*" of Theile and others. It is no less distinct in *Lemur varius*, *L. catta* and *L. nigrifrons*. It arises broadly from the ilium in *G. Garnettii*. In *Tarsius* (2), it is double and arises as high as the last dorsal; but comes from the last dorsal and six upper lumbar vertebræ in *Nycticebus*. In *L. catta*, *G. Allenii* and *G. crassicaudatus*, it comes from the last three lumbar vertebræ.

Subiliacus (*iliacus internus; see psoas posticus*) is continuous with *psoas posticus*. In the genus *Galago* this arises partly from the antero-superior spinous process of the ilium and partly from the body of the last lumbar vertebræ; while in *Nycticebus tardigradus*, we see that its name should be changed, since it does not arise at all from the ilium, but comes from the sacrum and lumbar vertebræ below the third.

Ectoglutæus (*glutæus maximus*) is very broad, and although thick posteriorly, becomes thin towards its anterior edge. The coccygeal and sacral part of its origin is like the same in man, but the remainder is thin, and fibres come from the aponeurosis over *mesoglutæus*, in a line from the anterior to the posterior iliac angles. The insertion begins about one inch below the trochanter major, on the linea aspera, as in *Hylobates leuciscus* (1), to its middle, while in the Gorilla this insertion continues to the knee. On the left side of the Orang it gives off a portion to insert with the short branch of the *biceps* on the femur. In the lemuroids it is large with a large caudal portion except in *Nycticebus*.

MESOGLUTÆUS (*glutæus medius*, Fig. 1, C) is generally much larger in Quadrumana than in man. Arising from the whole superior border of the ilium, from its anterior angle to the sciatic notch, through which an important fasiculus comes from the inner surface of the coccyx, it becomes thick, stout and long to attach by a short, strong tendon on top of the trochanter major.

ENTOGLUTÆUS (*glutæus minimus; scansorius*, Traill, Wilder, Bischoff, etc.; *invertor femoris*, Owen; see *pyriformis;* Fig. 1, A.). This muscle has really been *found in all the apes* though it has always been wrongly homologized in some, and in such cases was said not to exist. Although the form of the ilium in the Orang is quite peculiar, this muscle retains its ordinary relations to all the other iliac muscles. If, instead of the antero-inferior spinous process of the ilium of man, we had a large notch there making the neck very narrow as in the Orang, the origin of *entoglutæus* would necessarily occupy the same position relative to its edge. The difference here is in the bone and not in the relative position of the origin. It arises from the anterior margin and aspect of the external surface of the ilium and from its anterior angle down two-thirds of the way towards the acetabulum. As in man its origin is not very distinct from that of mesoglutæus. It is a thin, broad, triangular, and very important muscle, proportionally larger than that in man. On its anterior border is a partially separable fasiculus, *tensor fasciæ latæ?* The whole forms a stout tendon to insert on the anterior face of the trochanter major, but a little lower down than in man. In *Lemur nigrifrons* it arises from the whole border of the notch as in the Orang. The other lemuroids possess only a part of this origin and in *Galago* only a very small portion exists, coming from above the acetabulum, the muscle being very small and short.

TENSOR FASCIÆ LATÆ appears as an anterior fasiculus of *entoglutæus*, not very distinct. This is probably homologous with that of the other apes and man, since it agrees by its function and the relative position of its origin, and its insertion in man would not have to vary much to blend with that of *entoglutæus*. In the Chimpanzee it was much larger than in man, while in the higher apes it generally is more or less combined with the margins of the *glutei;* therefore we could hardly expect it to be absent from the

Orang. Also it is not differentiated off in the lemuroids except in *Tarsius*, where Burmeister describes it as not very distinct.

Pyriformis (*glutæus minimus*, Traill; Fig. 1, B.) in man arises from the external iliac margin of the great sacro-sciatic notch and by three small slips from the sacrum, to insert on the back part of the upper border of the trochanter major by a stout tendon usually blended with that of the *obturator internus*. In the Chimpanzee and Orang it differs from man's by not receiving the three sacral slips and by being inserted a little more anteriorly but just over the insertion of *obturator internus*, so that its position relative to that muscle is preserved. In the Lemuroidea it arises entirely from the sacrum.

Obturator internus is longer than man's, and inserts on the internal face of the great trochanter, far above the *gemelli*, instead of being blended with them as in man and the lemuroids.

Obturator externus is a large muscle, distinct to its insertion between the *o. internus* and the *gemelli*, except in the Lemuroidea.

Gemelli et quadratus femoris form one muscle, not easily divisible into fasiculi. As in the Chimpanzee, they are very long on account of the long posteriorly projecting ischium. They insert with the *obturatores* in the lemuroids.

Ileo-femoralis subrectus, a very small, round muscle, which arises between the two heads of the *rectus femoris*, and extends just beneath it, over the hip joint to attach anteriorly, at the base of the surgical neck between the two trochanters. It is common to both sides. Further, it has been found in the Chimpanzee by Wilder, and in *Hylobates leuciscus* by Bischoff, who speaks of it as "ein kleiner von der Spina ant. inf. Ossis Illii entspringender und sich an die Basis des Trochanter minor ansetzender Mueskel" and says that it also exists in *Cynocephalus maimon*, *Cercopithecus sabœus*, and *Macacus cynomolgus*, but gives it no name nor homologue. Curiously it was also found in *Didelphys virginiana* (Opossum), by Dr. Coues, where he regarded it as the homologue of the unfortunate so-called *scansorius* (*entoglutæus*). It exists in all these cases with so little functional importance that

it must be regarded as rudimentary, though quite distinct in the apes.

CIRCUMDUCTOR SUB-PECTINEUS (SUPERIOR ET INFERIOR Fig. 2, A, and B). I make these names indicate two muscles, which, so far as I know, have never been described and may be considered as new. From Dr. Coues' memoir I conclude that their homologues (like that of *ileo-femoralis sub-rectus*) exist in *Didelphys virginiana* (the Opossum). Homologues of one or more of these certainly exist in the Lemuroidea, since Van Campen (15) finds what he calls a fourth adductor arising *beneath pectineus*, and attaching to the small trochanter in *Perodicticus*. Meckel says that there are four adductors besides *pectineus* in *Loris*. In describing *pectineus*, Owen states that "beneath it are strong and thick gemelli converging from their origin on the anterior surface of the pubis and ischium to the interspace between the small and large trochanter" of *Cheiromys*. Owen is certainly mistaken in regarding these as *gemelli*. Together with the adductors of the apes these have generally been lumped as a group of fasiculi not to be understood; but I have homologized the adductores and find these circumductores left. They adduct and rotate the limb at the same time, whence the name *circumductores*. Each of these is a distinct muscle. They are inserted near the line of attachment of *adductor magnus*, but cannot be a part of it, because, if the insertion of that muscle was continuous as in man, to its upper factor, these would be left behind; furthermore, that which arises highest inserts lowest, and this is contrary to the general rule that parts of the same muscle do not cross each other.

CIRCUMDUCTOR SUB-PECTINEUS INFERIOR (Fig. 2, B.) is a very important muscle, being twice as large as *circ. s. superior*. Its origin is from the os pubis, between *pectineus* and *adductor magnus*, but close to the former, with which it agrees in breadth, though it is thinner. It passes posteriorly around the femur to attach just behind and below the highest fasiculus of *adductor magnus*.

CIRCUMDUCTOR SUB-PECTINEUS SUPERIOR (Fig. 2, A.) arises from os pubis close to *pectineus*, partly above and partly beneath the upper margin of that muscle. It passes downward and outward crossing *circ. s. inferior* to insert just below it. This also is very thin at both ends, though its attachments are broad.

Pectineus (see *circumductores* and *adductores*. Fig. 2, G–I.) is smaller than in man and its broad thin tendon, at the insertion, is not distinct from that of *adductor longus*.

Adductores. These muscles in the Gorilla are said to be like those of man, but in the other apes are usually found to be very indistinct so that they have generally been only partially homologized with those of man. *Adductor longus* and *adductor magnus* are found in all the apes, though the existence of *adductor brevis* has been questioned. I have figured those of the Orang. Perhaps the illustrations will explain them better than words. Their origin does not differ from the same in man. Bischoff discovered but two adductores in the Orang, saying, " Bei dem Orang Konnte ich nur eine Eintheilung in einen *Adductor longus* und *magnus* unterscheiden."

Adductor longus (Fig. 2, D.) agrees with that muscle in man by its size, form and relations, but is naturally separable from the *adductor magnus*, for only two-thirds of its length. Some of its fibres go below the foramen for the femoral vessels with *adductor magnus*. This is the smallest of the adductor muscles in the Lemuroidea, where it inserts in juxtaposition with *adductor magnus*, *a. brevis* and *pectineus*, but is continuous with *pectineus* in *Nycticebus tardigradus*.

Adductor brevis (Fig. 2, C.) arises as in man, but instead of becoming triangular, it continues narrow to its insertion, which agrees with the upper part of that in man. Bischoff failed to find it in the Orang, but found it in *Hapale penicillata* ("Von dem adductor magnus lässt sich aber ein starkes oberstes Bündel unterscheiden, welches vom aufsteigendem Ast des Sitzbeins entspringt und sich zwischen trochanter major und minor Ansetzt,") though he failed to homologize it as such. It is constant in the lemuroids.

Adductor magnus (Fig. 2, E–F.). The part of this muscle, which attaches to the internal condyle of the femur, is very thick and the foramen just above it for the femoral vessels is very large. Its insertion, instead of extending as high up as the base of the lesser trochanter as in man, stops at a point just above the upper margin of *adductor longus*. A small muscle partially di-

visible into two fasiculi is given off at the upper part of the origin of *a. magnus*, from which it seems to be a factor representing the upper border and insertion of that in man. *Ad. magnus* inserts over more than the middle third of the femur in *Lemur*, *Loris* and *Cheiromys;* into one-half of the femur in *Tarsius;* into the upper two-thirds in *Galago crassicaudatus;* into the lower two-thirds in *Nycticebus tardigradus.*

Semimembranosus, semitendinosus et biceps cruris arise together from the tuber-ischii by a broad, stout, fleshy origin. About three-fourths of an inch from this *semimembranosus* branches off to insert on the internal aspect of the inner condyle of the tibia. This muscle continues broad and fleshy to its insertion. It is found in the Chimpanzee with its tendon of origin long and its tendon of insertion short. *Semitendinosus* takes its departure at about one and one-half inches from the origin. It inserts by a very broad and thin tendon in a vertical line, internally on the upper third of the tibia. This muscle is not semitendinous as in man, but continues fleshy almost to its insertion. In *Lemur varius* this bifurcates to insert with both *gracilis* and *biceps*, while it has a double origin in *Hapale penicillata* and *Cheiromys*, where an extra portion comes from the second caudal vertebra adjoining the caudal origin of *glutæus*. *Biceps femoris*, at two and a half inches from its origin, divides into two branches. The longest of these goes to the external face of the head of the fibula and to the fascia anterior of the knee, while the shortest, receives a small factor from *ectoglutæus* and inserts externally, over the distal half of the femur, to the condyle. The short head of origin is a distinct muscle arising from the femur in the Orang, and probably represents that part of *vastus externus*, which is connected with *biceps* in the Lemuroidea.

Rectus femoris arises as in man and the lemuroids by two heads, while it has but one in the Chimpanzee, that from the inferior spinous process of the ilium.

Gracilis (Fig. 2, K.) comes from a broad, thin origin along the whole symphysis pubis, to attach below by a broad band between the insertions of *sartorius* and *semitendinosus*. It agrees with the same in the Chimpanzee by inserting lower down and by

being stronger than in man. In the lemurs it is inserted together with *sartorius* and *semitendinosus*, by a common tendon.

SARTORIUS (see *gracilis*), arising just below the angle of the ilium, becomes slender and very long. While that of man inserts on the inner tuberosity of the tibia, this attaches about one-third of the distance down that bone.

MUSCLES PROPERLY OF THE POSTERIOR LIMBS.

A.——— *arising from the femur.*

a.—inserting into the crural bones.

VASTUS EXTERNUS is not as large and strong as in man. It has two heads; the largest arising anteriorly, from the great trochanter; the smaller, from its base externally. Passing downwards as in man, it is attached to the external border of the upper margin of the patella, and, through this, into the tuberosity of the tibia. This is partly connected with *biceps femoris* in the Lemuroidea.

VASTUS INTERNUS takes its origin internally, from the base of the femur, to within one inch of the patella, on the internal margin of which it inserts. In *Tarsius* this appears to be in two layers; but the lower, is probably a part of the internal division of *crureus*.

CRUREUS is weaker than in man. It arises beneath the head of the femur, and from its whole anterior surface to within one inch of the patella, where it blends with the *vasti* to insert. It is a more distinct and important muscle in the Lemuroidea. The SUB-CRUREUS is a deep layer of the *crureus* from which it is seldom well differentiated off in the lemuroids, but is quite distinct in *Lemur*, *Nycticebus* and *Tarsius*, where, like the superficial *crureus*, it is divided to a greater or less extent, into an external and internal part. This probably arose as a deep factor of *crureus*, just as *crureus* arose as a deep factor of the *vasti*.

BICEPS FEMORIS SECUNDUS. I find the "short head" of *biceps femoris* (not its short branch of insertion) in the Orang, as a distinct muscle, which comes from the upper two-thirds of the outer lip of the linea aspera. It is inserted, between the *peronei* and the muscles posterior to them, along the whole length of the fibula.

This may represent that slip which connects *vastus externus* and the *biceps* in the Lemuroidea.

b.—inserting on the tarso-metatarsus.

Gastrochnemius is not so thick as in man. The external head is peculiar by being distinct throughout its entire length, even to its insertion, which is just beneath that of *soleus*, on the os calcis. The internal part and *soleus* unite as in man, by the distal third of their external edges and form the tendo Achillis. By this complete separation of the *gastrochnemii* we have two tendones Achillis as obtains in some marsupials. In the lemuroids the two heads are small and arise each by a sesamoid bone. They join with the strong tendo Achillis at the middle of the leg.

Plantaris is either absent from the Orang or else indistinguishably blended with *gastrochnemius*. In the lemuroids it is strong and arises in common with *gastrochnemius*, but has a separate tendon going to the fascia of the sole in *Lemur catta* and *Galago crassicaudatus*. Its tendon fails in *Nycticebus*, *Loris* and the Potto, where it is, as in the Orang, either completely blended with the *gastrochnemius* or else absent. It is also rather strong but united (9) with the outer head of *gastrochnemius* in *Hapale penicillata* and *Pithecia hirsuta*. In *Cynocephalus maimon* it is also very strong and inserts in the plantar fascia. From its important size and tendency to blend in the other apes, we must conclude that it is not absent from the Orang (as it appears to be), but that it constitutes a part of the external *gastrochnemius*.

c.—inserting on the toes.

Flexor digitorum communis longus fibularis (*flexor longus hallucis; see flex. dig. com. l. tibialis*) sends no tendon to hallux in the Orang but virtually becomes a *flexor digitorum*. *Flexor longus hallucis* is only the remnant of a *communis* muscle found in the lower animals. It is a very stout muscle, continuing fleshy to the tarsus. It arises from the external condyle of the femur, from the fascia of the knee and the upper two-thirds of the posterior surface of the fibula. Passing through the infero-internal groove of os calcis it bifurcates, sending one branch to the second toe, perforating the tendon of *flexor digitorum communis longus tibialis* (*flex. long. digitorum*) to insert with it on the last phalanx. The

other branch, after piercing the tendon of *flexor brevis digitorum*, inserts on the last phalanx of the third toe. In all the other higher apes it gives off tendons for the first, third and fourth toes, while that of *Hylobates* (1) acts also on the fifth. The tendon of the first toe is usually, though not always, absent from the Orang, and its other insertions seem very irregular. In *Lemur catta* and *Cheiromys*, it arises also partly from a distal, peroneal portion of the tibia and is considerably larger than *flex. dig. com. long. tibialis*, with which it blends distally in *Perodicticus*, where Van Campen (15) describes them together as one muscle. In the lemurs generally its tendons blend with those of its fellow (*flex. dig. com. long. tibialis*), to form the perforating tendons to the three middle toes. Notice has been taken of the great variability of the insertions of this muscle. Pagenstecher saw that the origin is more constant in its position, and consequently the only true character by which this muscle and its neighbor can be determined. Finding that one always arises chiefly from the tibia and the other from the fibula, he proposes the new and better names adopted here.

B.——*arising from the crural bones.*

a.—Inserting on the tarso-metatarsus.

Soleus (see *gastrochnemius*) comes from the posterior aspect of the head of the fibula by a narrow, stout tendon. It gradually grows fleshy and large for two-thirds of its length. Having attained its maximum diameter, it grows a little narrower, but continues quite large and fleshy to its insertion. By this peculiarity of form it is like man's *soleus* inverted, and does much to change the form of the leg. It has the same attachments in most all the apes. The tendo Achillis of *Hylobates leuciscus* is similar to that of man. It exceptionally arises along the greater part of the fibula in *Loris gracilis.*

Tibialis posticus (*extensor tarsi tibialis*) comes from the septa between the tibia and fibula and from the adjacent surfaces of these bones. It becomes tendinous where it passes behind the inner molleolus with *flexor digitorum communis longus fibularis.* This strong, round tendon attaches on the tuberosity of the scaphoid, and on the internal surface of the internal cuneiform bones, as in the Chimpanzee, without developing a sesamoid. ' In

the lemuroids it no longer deserves its name, *tibialis*, since its origin is from the tibial surface of the fibula almost to its summit. In *Galago* it goes only to naviculus, but also to ento-cuneiformis in the other Lemuroidea.

TIBIALIS ANTICUS (*flexor tarsi tibialis*) arises from the anterior and external surfaces of the proximal fourth of the tibia, from the fascia and intermuscular septa. It continues thick and fleshy to the annular ligament. Passing through the inner loop it attaches inferiorly on the internal cuneiform bone and the base of the metatarsal of the great toe. From these two attachments in the Chimpanzee it was divided into two parts as high as the middle of the leg, and this division in the Orang continues to its origin, forming *a distinct muscle* of the part, which acts on the metatarsal of the great toe. This double form attains to a greater or less extent in man and the higher apes, but it is single in *Hylobates leuciscus* where it attaches on the ento-cuneiformis. The single form is most common in the Lemuroidea, it being double to act also on the first metatarsal only in *Lemur varius*, *L. xanthomystax*, *L. nigrifrons* and *Cheiromys*, while its origin is extended over the upper two-thirds of the peroneal face of the tibia.

EXTENSOR METATARSORUM FIBULARIS (*peronei*). The so-called *peronei* have a common origin in the Orang, from the upper two-thirds of the postero-external surface of the fibula and from the intermuscular septa, but they soon divide and continue like those of man and the Chimpanzee, except that no sessamoid bone is developed on the tendon of the *longus* portion. A new name is here used since the *peronei* of man appear to be only remnants of this *extensor metatarsorum* as seen in the lemuroids, where it is a morphological integer, whose parts go to the various toes and have been called *peroneus quinti digiti*, *p. parvus*, *p. quarti digiti*, *p. tertius*, *p. brevis* and *p. longus*. Besides the ordinary *longus* and *brevis* portions, a third part, *p. tertius*, is often found, and acts on the fourth and fifth toes by inserting on their extensor tendons. Owen did not find it in the Orang, but in mine it is a very important muscle. Below the annular ligament it gives off a small factor to unite with the extensor tendon to the fourth toe, while its main part continues onward to blend with the extensor of the fifth toe. Bischoff (1) says he could not find *p. tertius* in any of

the apes, while he describes it in the Chimpanzee as a new muscle, a *third tibialis anticus*, "welcher im Anfang gemeinschaftlich mit dem extensor digitorum longus entspringt, sich aber bald von ihm trennt, und an der Fussbeuge in zwei feine Sehnen übergeht," etc. Wyman found it in *Mycetes*, and Meckel described it in the lemurs, while it exists generally in the Lemuroidea, where the two halves are separated up very high so that Mivart and Murie have described them as two muscles, *peroneus quarti digiti* and *p. quinti digiti*. Burmeister names them *extensor longus quarti digiti* and *extensor longus quinti digiti*. Failing to see that these two fasiculi with new names and those of *p. tertius*, are morphologically the same, Murie and Mivart failed to see that they were homologous, and wrongly say that *peroneus tertius* does not exist in the Lemuroidea, evidently thinking that it has no representative there.

The *longus* and *brevis* portions attach on the two external metacarpals, the latter having two tendons. The other factors were probably extensors of the two median metacarpals, but have been transferred from their primitive insertions to insert on the tendons of the *extensor digitorum*, by means of which their action is extended to the toes. The portion usually going to the fourth toe does not exist in *Galago*. This and that to the fifth also, is absent from *Loris gracilis*. Bischoff speaks of that part to the fifth toe as *peroneus parvus*, and found it in *Hapale penicillata* only as a branch from *p. longus*, but it was distinct in *Macacus cynomolgus*, *Cercopithecus sabœus*, *Pithecia hirsuta* and *Cynocephalus maimon*. In most of the lemuroids the origin is not only from the fibula, but also, in most cases, it arises on a small portion of the upper part of the tibia.

b.—Inserting on the toes.

Extensor digitorum longus is not essentially peculiar in this, though in Owen's Orang there was no tendon to the second toe. In the lemuroids it acts on the four peroneal digits, joining with the tendons of *ext. brevis* to the second and third, while that to the fifth is acted on by a tendon of *extensor metatarsorum fibularis*. Its origin is from the head of the tibia and the inner side of the fibula. In *Nycticebus tardigradus*, *Cheiromys* and *Loris gracilis*, two parts of the origin are found separated by an interval so that it appears to have a double head. In *Lemur xanthomystax* and sometimes in *L. catta* a small anterior fasiculus is given off to act on the

second, third and fourth digits, that to the fifth uniting with the other extensor tendon to the same. In *L. varius* it also exists and sends tendons to the third, fourth and fifth digits. Does this represent in the foot the *extensor digitorum communis profundus* (the so-called *extensor indicis proprius*) of the arm?

EXTENSOR PROPRIUS HALLUCIS arises just beneath *ext. dig. long.*, generally with no peculiarities.

FLEXOR DIGITORUM COMMUNIS LONGUS TIBIALIS (*flexor longus digitorum*), has its origin from the proximal two-thirds of the posterior surface of the tibia, and from the intermuscular septa between it and *tibialis posticus*. It is fleshy to where it passes behind the internal malleolus with *tibialis posticus*. It then divides into three factors to insert on the last phalanges of the first, second and fourth toes. The second of these is perforated by *flex. dig. com. long. fibularis* (*flex. long. hallucis*), while the last mentioned perforates *flex. dig. brevis*. In the Chimpanzee it has but two tendons, to the second and fifth toes. With this muscle also, as with *flex. long. hallucis*, Pagenstecher saw that the relative position of the origin was the only constant character. From this he gave the appropriate name adopted here. In *Nycticebus* and *Loris gracilis*, a small part of its origin is from the femur, and its factors to all the toes are blended with the corresponding ones of *flex. dig. com. long. fibularis* to form the perforating tendons. The latter muscle does not assist to the little finger in the lemuroids.

C.——— *arising from the tarso-metatarsus.*

a.—inserting into the toes.

EXTENSOR DIGITORUM BREVIS (*et extensor brevis hallucis*) arises by three fasiculi and sends tendons to all the toes. One part, from beneath the heads of the tibia and fibula, acts on the middle toes. The others, two, arise lower down and go to the first and fifth toes. The fasiculus inserting on the second phalanx of the first toe, has generally been called *extensor hallucis brevis*, but it is no more distinct nor important than that to the fifth, as may easily be seen in many of the lower forms. The extensor to the fifth toe is not very common in the apes, but Bischoff is certainly mistaken when he says that it does not exist at all in the Quadrumana. *Ext. dig. brevis* of the lemuroids, often has very import-

ant variations in the same species. It arises from the superior face of the cuboid, entocuneiform, navicular, and the anterior part of os calcis. It may consist of two, three, four or five portions. All its fasiculi are present in *Nycticebus tardigradus*, where it has five. That arising from the outer faces of astragalus and the calcaneum and inserting on hallux, is undoubtedly the morphological representative of that which is more widely differentiated off and called *ext. brevis hallucis* in some higher forms. Its second belly has a similar origin but goes to the peroneal side of the fourth digit. The other three arise together and go to the second, fourth and fifth toes. Thus by irregularity of the insertion the third toe receives none. In *Lemur*, *Galago Allenii* and *G. crassicaudatus*, it sends tendons to the three middle toes, sometimes to hallux and often to the little finger. It has three parts in *Tarsius;* to the first (*ext. brev. hallucis*), second and third (*ext. digiti tertii*, Burmeister) toes. Only two slips attain in *G. Garnetii* and *Perodicticus*, those from os calcis; one delicate and inserting on the tendon of *extensor longus digitorum* to the second toe; the other, strong, the extensor of hallux. Hallux and quintus receive no tendons from it in *Cheiromys*.

Flexor brevis digitorum pedis (*flexores breves digiti tertii, quarti et quinti, flexor brevis digiti secundi et flexor brevis hallucis superficialis*, Burmeister), arises similar to that in man, forming fasiculi with tendons to attach on the second phalanges of all except the second toe. The fasiculus to the first, has a distinct origin under that of the others. The tendon to the third is pierced by a factor of *flex. dig. com. long. fibularis* (*flex. long. hallucis*) to the same dactyl, while that to the fourth is perforated by a factor of *flexor longus digitorum*. In man there is a tendon to the second, but none to the first toe, and all are perforated by the corresponding parts of *flex. long. digitorum*. In Owen's Orang a small tendon went to the second toe. In the Gorilla, *Cynocephalus*, *Pithecia* and Chimpanzee it has only two fasiculi, those to the second and third toes; while in *Hylobates*, *Cercopithecus* and *Macacus*, it has only one tendon, that to the second toe, and in *Hapale*, that to the fifth. In *Lemur catta* one of these fasiculi comes from the flexor tendon forming half of the perforated tendon to the third digit and the whole of those to the fourth and fifth. The same is true of *L. varius*, *Cheiromys*, *Tarsius* and *Galago Allenii*, except that

it furnishes the whole of the tendon to the third. In *Nycticebus* it acts only on the fourth and fifth toes. The other fasiculus goes from the plantar fascia and attaches by a perforated tendon on the second toe, also forming one-half of that to the third, in *L. catta*. It acts only on the second toe of *L. varius*, but goes also to the hallux in *G. Allenii* and *Tarsius*.

Abductor digiti minimi, opponens digiti minimi and abductor ossis metacarpi digiti quinti of the Orang, do not differ essentially from those of the hand, *opponens* being absent. The first of these is very large in the Lemuroidea, and arises from the under surface of os calcis, while the last (*abd. os. m. d. q.*) is diminutive, arising from the peroneal side of os calcis. In *L. nigrifrons* it is partly fused with the abductor.

Flexor brevis, abductor and adductor hallucis of the higher apes, are not essentially different from those of man, but are inclined to be double. *Adductor hallucis* and *transversus pedis* together, are represented by a single slip from the third metatarsal in *Lemur catta*. In the other lemurs these muscles are more or less separable and divisible.

Lumbricales. These very small, round muscles arise from the tendons of both *flex. dig. com. long. tibialis* and *flex. dig. com. long. fibularis*, to insert on the first phalanges of all the dactyls except the first. So in the lemuroids, except *Nycticebus*, which has none to the index.

Interossei pedis. All the higher apes have two extra superficial *interossei externi*. These often attain in the lower apes. In *Tarsius* they act on the second and fourth, and in *L. catta* on the second and fifth digits; *Galago Allenii* has three pairs of *deep interossei*, while the other lemuroids have a pair for each dactyl except the hallux. Deep in the *planta pedis* Bischoff finds the small *musculi contrahentes digitorum* in all the higher apes except the Orang and Gorilla.

MUSCLES TELEOLOGICALLY OF THE ANTERIOR LIMBS.

A.——— *arising from the body.*

a.—inserting on the shoulder-girdle.

Trapezius, by its origin, overlaps *latissimus dorsi* as in man, while in the Chimpanzee it does not, the two being continuous.

On the right side it blends with *levator claviculi* at its insertion. Its attachment has an interval near the proximal end of the scapular spine of the right side and two intervals near the same place on the left. It arises from the spines of the first nine dorsal vertebræ and the ligamentum nuchæ, to the middle of the neck in *L. catta*, and, from the whole of the lig. nuchæ and the back of the skull in *Cheiromys*. Its origin extends back to the eleventh dorsal spine in *Galago*, to the twelfth in *Tarsius*, to the fifth in *Nycticebus*, and to the seventh in *Cheiromys*. In *Lemur catta* it inserts on the whole anterior margin of the scapular spine to the extremity of the acromion process, and to nearly half of its posterior margin.

RHOMBOIDEI form a single muscle in the apes generally, Bischoff (1) finds the *rhomboideus capitis* in the Orang. It arises from the occiput and inserts beneath the anterior margin of *rhomboideus* in *Cynocephalus maimon*, *Cercopitheus sabœus*, *Macacus cynomolgus*, *Lemur*, *Nycticebus* and *Cheiromys*. *Rhomboideus* proper arises from the spinous process of the last two cervical and first four dorsal vertebræ in *L. catta*, from the third cervical to the fourth dorsal in *Galago crassicaudatus*, from the fifth cervical to the fifth dorsal of *Nycticebus*, from the whole ligamentum nuchæ and to the second dorsal in *Cheiromys*. In *Cheiromys* there is no limit between *rhomboideus* and *lat. dorsi*.

SERRATUS MAGNUS (*et levator anguli scapulæ*). The magnus portion of this muscle comes from all except the twelfth rib. The superior portion comes from the last cervical vertebræ and is separated from the other part by an interval. It arises from the first eight ribs in *L. catta*, *Cheiromys* and *G. crassicaudatus*, from ten ribs in *Nycticebus*, from eleven in *Perodicticus*, from the second to the ninth in *Tarsius*, from six in *G. Allenii*. In the latter species as well as in *Cynocephalus*, *Maimon*, *Cercopithecus sabœus*, *Macacus cynomolgus* and *Hapale penicillata*, it is inseparably conjoined with the *levator anguli scapulæ*, and is probably likewise in *L. varius*. We here see that the latter muscle is but a part of *serratus* differentiated off in the anthropoids. In the lemuroids generally, this cervical *serratus* (*lev. ang. scap.*) is a continuous part of *serratus magnus* which arises from all the cervical vertebræ of *L. catta*, from the five anterior vertebræ in the Potto, and from the six hindermost cervical vertebræ of *Tarsius*. In the Orang it is dis-

tinct and divisible into three fasiculi on the left side, and into two on the right. Also in the Gorilla, Chimpanzee, and *Hylobates leuciscus*, it is a distinct muscle like that of man. It goes to the outer end of the clavicle in *Nycticebus* and *Loris*, to more than the middle third of the spine of the scapula in *Cheiromys*, and to the metacromion process of the scapular spine in *Lemur*.

Omo-cervicalis (*levator claviculæ*, *cleido-cervicalis*, *acromio-cervicalis*, *levator anticus scapulæ*) is not found in man, but here and in the Chimpanzee it is quite strong. I find it slightly blended with *trapezius* on the right side. It always arises from the transverse process of atlas, but with the following insertions; on the acromial end of the clavicle in the Gorilla, Orang, Chimpanzee, *Hylobates leuciscus*, *Loris gracilis*, and *Nycticebus tardigradus;* on the metacromion process of *Macacus cynomolgus;* on the large process of the scapular spine in *Lemur;* on more than the middle third of the scapular spine in *Cheiromys*.

b.—inserting on the humerus.

Pectoralis (*major et minor*) forms one morphological integer, which is often divided into two or more parts. The (*pectoralis*) *minor* portion is generally treated as a distinct muscle. In *Galago Allenii* only one large *pectoralis* muscle exists. In *Loris gracilis* a (*pectoralis*) *minor* portion is partly differentiated off, while a third or inferior part also exists. The minor portion is large and inserts on the capsular ligament of the humerus in *L. catta* and *G. crassicaudatus*, on the outer edge of the bicipital groove in *Tarsius*, on the great tubercle of the humerus in *Perodicticus*, *Cheiromys* and *Loris gracilis*, on the processus coracoideus in the Orang, Gorilla, and *Hylobates leuciscus*, on both the coracoid process and the ligamentum coracoacromiale in *Cynocephalus maimon*, *Cercopthecus sabæus*, *Macacus cynomolgus* and *Hapale penicillata*, on both the coracoid process and the head or capsule of the humerus in *Pithecia hirsuta* and *Troglodytes niger*. The *major* portion divides again into three parts in *L. catta;* a clavicular part, from the sterno-clavicular junction and the innermost fourth of the clavicle, inserting on the ulnar side of the deltoid ridge; the sternal portion, the longest, arising from the sternum and sternal ends of the cartilages of the sixth, seventh and eighth ribs, attaching on

the margin of the bicipital groove in juxtaposition to the clavicular portion; the abdominal part comes from the sheath of the *rectus* forwards to the origin of the second part and backwards to the cartilage of the tenth rib, and inserts in close union with the second part. In *Galago* the anterior and posterior parts are very delicate or absent. The clavicular part does not exist in *Nycticebus* and *L. varius*, while the posterior part does not appear in *Loris gracilis*. The posterior part in *Tarsius* is present but not separable. The (*pectoralis*) *major* part inserts by three tendons in the Orang. Of these the anterior one is nearly as broad as the other two together.

Latissimus dorsi inserts by two very strong tendons. The inferior of these blends with *teres major* in a common inserting tendon. The superior insertion, which exists in the other apes and man, is not peculiar except that its auxilliary, the so-called *dorso-epitrochlearis* (q. v.) assumes an unusual importance by its size. The *latissimus* of *L. catta* and *Tarsius* comes from the lumbar fascia and spines forwards to the sixth, from the ten hindmost dorsal vertebræ in the Potto, from the last five ribs and the common tendon of *erector spinæ* in *Cheiromys*. In this last animal it is indistinguishably united with *rhomboideus*. It sometimes sends slips to the *pectoralis*.

Deltoideus is powerful, tendinous and fleshy to the insertion. It arises from the outer half of the clavicle, from the acromion process, from the whole crest of the spine of the scapula, and (by fascia) from the proximal border of that bone. It is inserted over the second quarter of the outer surface of the humerus. In the Chimpanzee there is an additional *infra-spinatus* portion of this muscle arising from the fascia of the *infra-spinatus* muscle and from the lower third of the anterior border of the scapula. It is a close morphological relative of the *spinati* and *teres* muscles; the latter are probably its offspring. With *Cheiromys* and the lemurs three portions of the origin exist; one from only the acromion process inserts with another, which arises posteriorly, from the scapular spine. The third part goes from the middle third of the clavicle to between the insertions of the former part, and that of *pectoralis major*. In that of *Galago Allenii*, *Loris* and *Nycticebus*, no distinct lines of separation exist. Two portions, partly united, are found

in *G. peli.* The insertions of the parts are generally distinct though near together.

Teres major and minor are generally not peculiar in the apes, but the latter is closely connected with *infra-spinatus* in *Cheiromys*, and arises partly from its dorsum in *G. Allenii*, while its insertion blends with the distal one of *latissimus dorsi* in the Orang.

Supra-spinatus and infra-spinatus have no essential peculiarities.

Coraco-brachialis in the Chimpanzee arose with the short head of biceps and its tendon. Its insertion, about one-third of the way down the humerus was not more than half an inch long. In the Orang it does not vary much from that of man, since it arises with the short head of biceps, from the coracoid process, is quite stout and inserts about mid-way of the humerus. It is likewise in the Gorilla, *Hylobates leuciscus* and *Hapale penicillata.* With *Cercopithecus sabœus* and *Macacus cynomolgus*, a superior portion exists inserting on the spina tuberculi minoris. Its head is double in the lemuroids, where its origin is generally low. The *coracobrachialis* and *biceps* originate from a sesamoid bone on the coracoid process.

Subscapularis in *Tarsius* and *Cheiromys* is slightly divisible into three fasiculi.

c.—Inserting on the cubitus.

Biceps brachii is in no way peculiar, though in the Chimpanzee its two heads are distinct to within an inch of the insertion, and the coracoid head is the larger.

Multiceps extensor cubiti (*quadriceps extensor; anconeus primus*, *secundus*, *tertius*, *quartus*, *quintus* and *sextus; latissimo-condylus or dorso-epitrochlearis et triceps*). The *triceps* of man and the higher apes becomes a quadriceps by its internal head dividing off an extra fasiculus with various degrees of distinctness in the lemuroids. This division is very indistinct from its fellow in *Nycticebus*, while in *Cheiromys* and *Tarsius* it is quite separate, and an important interval exists between them in *Stenops* (13).

Further, the lemuroids show that *anconeus* is but a continuation of the same muscle, making a *quinticeps* of it except in *Cheiromys*, where it is quite distinctly differentiated off. Moreover, it is most probable that *latissimo-epitrochlearis* is a factor from the same muscle. This latter portion (*dorso-epitrochlearis* or *latissimo-condylus*) arises from the tendon of *latissimus dorsi* as in the other apes. It inserts on the condylus internus and ligamentum intermusculare in the Orang and Gorilla; into the condylus internus in *Troglodytes niger*, *Cynocephalus maimon*, *Cercopithecus sabœus*, *Macacus cynomolgus*, *Pithecia hirsuta* and *Hapale penicillata;* into the lig. intermusculare to the middle of the humerus in *Hylobates leuciscus;* on the internal face of the olecranon process of the Lemuroidea, except in *L. varius* where it attaches to the shaft of the ulna.

In the two last-mentioned muscles a direct transition is seen from those arising on the shoulder girdle to those arising from the humerus.

MUSCLES PROPERLY OF THE ANTERIOR LIMBS.

A.——*arising from the humerus.*

a.—inserting on the cubitus.

BRACHALIS ANTICUS AND PRONATOR RADII TERES are in the Orang as in man, but those of the Lemuroidea are very large.

SUPINATOR LONGUS arises very high on the humerus of the Orang. Its insertion is into the styloid process in *Galago* and *Lemur varius;* more proximal in *L. catta* and *Tarsius;* into the middle of the radius in *Hylobates leuciscus;* into the deep palmar fascia and the pisiform bone of *L. xanthomystax* and *L. nigrifrons.*

b.—inserting on the carpo-metacarpus.

PALMARIS LONGUS, EXTENSOR CARPI RADIALIS LONGIOR, EXTENSOR CARPI RADIALIS BREVIOR, EXTENSOR CARPI ULNARIS, FLEXOR CARPI RADIALIS and FLEXOR CARPI ULNARIS have no essential peculiarities.

B.——arising from the cubitus, etc. etc.

PRONATOR QUADRATUS is not essentially peculiar.

SUPINATOR RADII BREVIS extends from the proximal third of the ulna to the proximal third of the radius nearly at right angles

to the axes of these bones, and is quite strong. Bischoff finds it in all the higher apes like the same in man; and what Pagenstecher describes as *sup. rad. brevis* with an origin from the lower third of the linea aspera (angulus internus s. lateralis) adjoining *brachialis internus* and inserting on the tuberositas ulnæ, is only a division of *brachialis internus*. This same mistake is made by Murie and Mivart (9) in the Lemuroidea.

Flexor sublimis digitorum. The fasiculi of this muscle near their origin are not distinct from each other. Otherwise it is like that of man. In the Chimpanzee, Wilder finds that ón the left side it agrees with this, but on the right, it sends two tendons to the ring-finger and the little finger receives none. The index finger receives no tendon in *Perodicticus* and *Nycticebus*. It sends tendons to the four external digits of all the other monkeys, and besides these, a fifth, which in *Hapale penicillata* and the lemuroids joins the tendon of *flexor profundus*.

Extensor digitorum communis (*et extensor digiti minimi proprius*). The part of this muscle which is usually called *ex. dig. com.*, in the Orang has tendons to the four fingers, while the part usually called *ex. dig. minimi proprius*, sends a tendon to each of the phalanges of the little finger, besides giving a fourth to join that of the *ex. dig. com.* to the third finger. That these two muscles together form one morphological integer, is seen where they arise as one muscle—an *extensor communis*—from the external condyle representing also the *ex. dig. m. proprius*, which is not at all differentiated off in the Potto, *Loris gracilis*, *Cheiromys*, *Nycticebus tardigradus*, and *Galago crassicaudatus*. In *G. Allenii* this marginal portion is partly separable, while in the lemurs it becomes a distinct part—an *ex. dig. m. proprius*. For other reasons this can no longer be called *ex. dig. m. proprius*, because it generally has two tendons respectively going to the fourth and fifth fingers, while in the lemurs one or the other of these parts often fails, so that it is sometimes *extensor quarti digiti*, although it usually acts on the fifth finger. It is very constant as an extensor of the little finger alone in *Loris gracilis* and *Nycticebus tardigradus*. The main part of this muscle gives off four tendons to the four ulnar digits in *Lemur varius*, *Tarsius*, *Loris gracilis*, and *Galago*, though the two ulnar tendons sometimes bifurcate. That

of *Perodicticus* sends two tendons to the fourth, one to the third and one to the fifth finger. In *Nycticebus* it has five tendons whereof the fourth digit gets two. It is divided into two halves to above the middle of the forearm of *Cheiromys;* of these, the radial belly gave tendons to the index, third and fourth digits; its ulnar belly sends tendons to all the digits except pollex.

Extensor digitorum profundus (*extensor indicis proprius et extensor pollicis longus proprius*). At first I thought *extensor indicis proprius* was absent from the Orang, but found what seemed to be a new muscle to which I gave the above name appropriate to its situation and function; but afterwards, from its relative position I determined it to be the homologue of *extensor indicis proprius*, although it is a *flexor digitorum* inserting on the three middle fingers of the Orang. It has a narrow origin between the proximal thirds of the ulna and radius, from the superior fascia of *supinator brevis*, from the posterior aspect of the ulna and from the interosseous membrane on the ulnar side. It divides into three fasiculi; the upper and largest fasiculus, which goes to the ring-finger, being distinct almost to its origin; while the other two, separate a little above the annular ligament where they become tendinous. They insert on the bases of the three middle fingers, each by a broad aponeurosis. In *Pithecia hirsuta* there exists a *flexor digitorum communis profundus* representing both *extensor pollicis longus* and *extensor indicis proprius*, acting on the thumb and first three fingers. This same *communis* form attains also in *Hapale penicillata*, but the thumb receives two tendons instead of one. The portion to the thumb is more distinct in the higher apes where it is generally single as in man. The indicial portion is like that of man in the Gorilla alone. In *Hylobates leuciscus* it has three tendons all acting on the medius finger, but in all the other higher apes it has two tendons acting on the index as well as medius. In the lemuroids we see again that this muscle as found in man is but a remnant of an *extensor digitorum communis*. It sometimes acts as an extensor of index alone in *Loris gracilis* and the lemurs, but their third finger usually receives also a tendon. That of *Galago* and *Tarsius* attaches rather constant to both the second and third digits. *Lemur catta* has it as an *extensor* of the three middle fingers, and its parts are only separate from the wrist onwards. These are divisible into the belly of the

muscle in *Cheiromys*, where it is still more complex since the indicial part is very delicate, but sends an additional factor to medius, while the middle one is the largest and gives off an extra slip to assist that to the fourth. It goes either to the second and fourth or to the second and fifth digits in *Nycticebus* and *Perodicticus*. From these complex and various insertions it is plainly seen that we can no longer speak of *extensor pollicis longus proprius* and *extensor indicis proprius*, as distinct muscles, but rather as more or less differentiated parts of an *extensor digitorum communis profundus*. The most important part of it often goes to the median finger as in *Cheiromys* and *Lemur xanthomystax*. In the latter this is as distinct as a separate muscle, and is the homologue of the radial extensor of the third finger sometimes found in man as *extensor medii digiti*.

Flexor digitorum communis profundus (*et flexor pollicis longus proprius*). That *flexor pollicis longus* of man is only a differential part of *flexor digitorum com. profundus*, is plainly seen, although Bischoff says that it does not exist at all in the apes, while at the same time he describes it as a minor part of *flexor digitorum communis profundus*, failing to see its homological value. Mivart, Murie, and others, are equally mistaken in describing the major part of *flexor dig. com. l. profundus* as the *flexor pollicis longus proprius*. It is said not to exist in the Orang because the thumb receives no tendon, and it is not distinguished from the *flex. dig. c. l. profundus*. In the Gorilla it goes to the two first digits, that to the thumb being the weaker, while the *flexor dig. c. l. p.* acts on the other three fingers. In the Chimpanzee *f. d. c. l. p.* has its belly divisible into three portions; of these the radial one represents the so-called *flex. poll. proprius longus* and sends one of its tendons to the thumb. It maintains the same insertions in *Hylobates leuciscus*, but is not in the least separable from the *fl. dig. com. l. profundus*, which exists here with one large entire belly in its typical form flexing *all* the digits. The same is again seen in *Hapale penicillata*. In all the other apes it exists as one large *flexor communis*, usually having a single tendon at the wrist which sends the deep flexor tendons to all the fingers and the thumb also, except in *Perodicticus* where the index receives none. The proximal part of the belly however, is often more or less divided; two main parts, one radial and the other ulnar are most common.

Of these the pollical half is generally the largest in the lemuroids. Minor partial divisions often exist also, so that there are four parts of the original belly in the galagos and *Macacus cynomolgus*.

OPPONENS MINIMI DIGITI seems to be absent from the Orang, but the other muscles of the little finger do not differ particularly from those of man. The *opponens* is distinct in the lemuroids.

EXTENSOR OSSIS METACARPI POLLICIS of the Orang, is smaller than the EXTENSOR POLLICIS PROPRIUS, but is quite large in the Chimpanzee. The other muscles of the thumb not already mentioned in the Orang are like the same in man. FLEXOR BREVIS POLLICIS is generally not altogether distinct from the ABDUCTOR POLLICIS in the lemuroids, where this latter muscle arises from the annular ligament and a sesamoid bone in front of the trapezius. *Abd. pollicis* has a double insertion in *Hylobates*, *Cercopithecus* and *Macacus*, while a tendency to division is noticed in some other species. The Lemuroidea have a large ADDUCTOR POLLICIS arising from the whole length of the third metacarpal and the base of the second and the palmar fascia. In *Tarsius* and *Lemur xanthomystax*, it is more or less divisible into two parts, while a distal fasiculus of it represents a TRANSVERSUS MANUS, of which the *adductor pollicis* would seem to be a differentiated part. This homotype of *transversus pedis* is strikingly distinct in the Aye-aye. This *adductor* (*transversus*) is likewise united with AD. OBLIQUUS in the higher apes, except in the Chimpanzee, *Cynocephalus*, *Pithecia hirsuta* and *Hapale penicillata*. The *lumbricales manus* do not differ from those of man. Only three exist in *Galago Allenii*, *Cheiromys* and *Perodicticus*, but the other lemuroids have four.

INTEROSSEI MANUS. The dorsals were very small while those of the palm were largely developed in the Orang. In the Lemuroidea each digit except pollex has a pair of *interossei* (*flexores breves*), ABDUCTOR MINIMI DIGITI being one. These are more or less divisible into internal and external (palmar and dorsal) layers. FLEXOR DIGITI MINIMI is not distinct from the abductor except in *Lemur varius* and *L. xanthomystax*. In *Galago*, *Cheiromys* and *Tarsius*, two superficial interosseal slips exist. Deep in the vola manus as well as in the planta pedis, Bischoff finds small MUSCULI CONTRAHENTES in all the higher apes except the Orang and Gorilla.

REFERENCES.

1. *Bischoff*. Beitraege zur Anat. des Hylobates leuciscus u. zu einer vergl. Anat. der Mueskeln der Affen u. des Menschen, Muenchen, 1870.
2. *Burmeister*. Beitræge zur Kenntniss der Gattung Tarsius, Berlin, 1866.
3. *Coues*. Antero-posterior symmetry with special reference to the muscles of the limbs. The Medical Record, New York, 1870.
4. *Duvernoy*. Des charactères anatomiques des grands singes pseudo-anthropomorphes. Archives du Museum, VIII, 1855.
5. *Gegenbaur*. Vergleichende Anatomie, Leipzig, 1870.
6. *Huxley*. On the Position of Man in Nature.
7. *Koelliker*. Entwickelungsgeschichte des Menschen u. d. hoeheren Thiere, Leipzig, 1861.
8. *Meckel*. Anat. Comp. Traduit par MM. Riester et Alph. Sanson, 1830.
9. *Mivart and Murie*. On the Anat. of the Lemuroidea. Zool. Trans., Vol. VII. Part I.
10. *Oken*. Physiophilosophie.
11. *Owen*. Anat. of the Orang-utan (Simia satyrus). Proc. of the Committee of Science, etc. Zool. Soc. London. Part I, 1830.
    a.———— Cheiromys. Trans. Zool. Soc., Vol. V.
    b.———— Comparative Anat. of Vertebrates.
12. *Pagenstecher*. Zoologischer Garten, VIII, 1867.
13. *Schroeder van der Kolk & W. Vrolik*. Stenops. Bijdragen tot de Dierkunde, uitgegeven door het Koninklijke Zoologisch Genootshap Natura Artis Magistra, Erste Deel. Amsterdam, 1848-54.
14. *Traill*. Observations on the Anat. of the Chimpanzee. Wernerian Transactions, Vol. III, 1818.
    (This was not a Chimpanzee, but an Orang.—W. S. B).
15. *Van Campen*. Verhandelingon der Koninklijke Akademie van Wetenshappen. Amsterdam, 1859.
16. *Wilder*. On Morphology and Teleology. Mem. Bost. Soc. Nat. Hist., Vol. I.
    a.———— Intermembral Homologies. Proc. Bost. Soc. Nat. Hist., 1871.
    b.———— Contributions to the Comp. Anat. of the Chimpanzee.
17. *Wyman*. Symmetry and Homology in limbs. Proc. Bost. Soc. Nat. Hist., 1867.

EXPLANATION OF FIGURES.

FIG. 1. A, ENTOGLUTÆUS.
B, PYRIFORMIS.
C, MESOGLUTÆUS.
D, D, OBTURATORES.
E, E, QUADRATUS FEMORIS.

FIG. 2. A, CIRCUMDUCTOR SUPERIOR.
B, CIRCUMDUCTOR INFERIOR.
C, ADDUCTOR BREVIS.
D, ADDUCTOR LONGUS.
E—F, ADDUCTOR MAGNUS.
G—I, PECTINEUS (Origin and insertion).
K, GRACILIS.
L, ILIUM.
P, OS PUBIS.

Fig. 1.

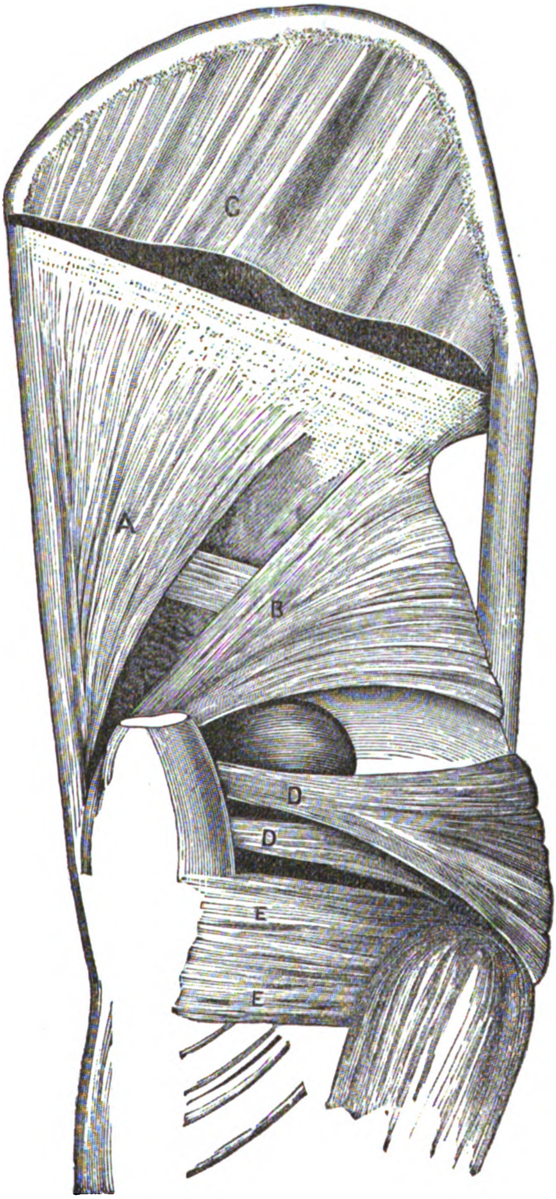
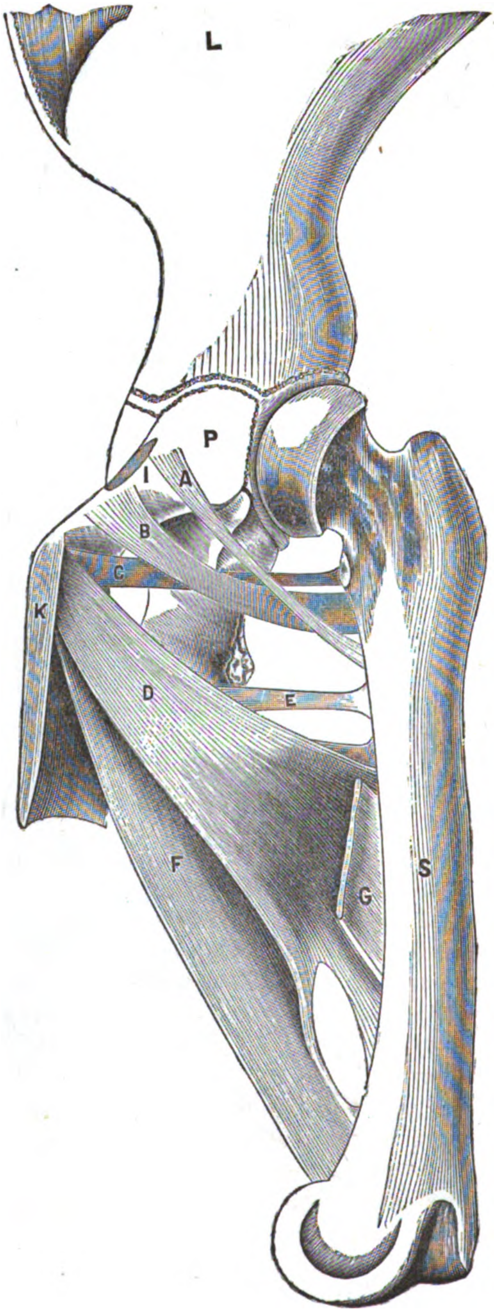


Fig. 2.



Observations on the Development of Didelphys Virginiana.

By W. S. Barnard, of Canton, Ill.

(ABSTRACT.)

Didelphys Virginiana, the Opossum, is our typical and only representative of that large order of peculiar mammals known as Marsupials, yet almost nothing is known of its development. A knowledge of the mode of origin and formation of the marsupial pouch which characterizes them must throw much light on their relationship to allied groups. The external skin extends into the pouch as its internal lining, and the whole seems to be formed by an infolding of the skin. Its cavity opens on the median line of the abdomen, and extends backward and laterally, forming a kind of double pocket, in the bottom of which the milk glands open through long papillæ. The young develop in twenty-four to twenty-eight days, are then born as helpless little bodies about one-half an inch long, with mouth and fore limbs well developed. The parent must place them in the pouch, attaching each to a gland, which the embryo grasps firmly between its lips and helps hold fast by the sharp claws of its fore feet. The corners of the mouth gradually grow up so that it cannot let go, and thus hangs for several weeks until its adult characteristics are acquired.

Below the Marsupials stand the Monotremes, including the remarkable Australian Ornithorhynchus and Echidna. In the former the openings of the milk glands upon two areas of the abdomen are not marked by any elevation or depression; but in the Echidna we find similar glands, the openings of which become depressed at maturity, each forming a small pit, into which the nose of the young is inserted and attached, where it remains pendant and nourished while its development advances. This pair of little pits may be regarded as the beginning of the double pocket so largely developed in marsupials. At the same time these depressions are just the opposite of what obtain in the higher mammalia, where the gland opening is marked by larger or smaller abdominal or pectoral prominences. The milk glands of the Ornithorhynchus are typical, while the depressed glands of the Echidna and the elevated glands of higher mammalia may be regarded as differentiations of the same. The young Opossum develops no placenta, but has a kind of umbilicus. The cicatrix of this seen by Owen in the embryo kangaroo wrongly led

to the supposition that a placenta might have been detached. At birth its hind limbs appear as short stumps, each with a flattened end, presenting five slight marginal elevations, the beginnings of the toes. The toes and legs gradually elongate. Soon each of the two middle toes gets a joint, and the inner toe becomes set off from the rest. Later all the fingers show two joints, and the inner toe becomes a thumb with two joints while each finger has three joints; and now the hind foot closely resembles the hand of man and the higher quadrumana, while its fore feet, developed much earlier, remain quite animal-like. The hind limbs are primarily much shorter than those in front, but develop so fast as soon to catch up and outgrow the others. The same is true of the young kangaroo, where the hind limbs eventually become several times larger and longer than those in front. At first the eyes are covered beneath the skin and the ears represented by small elevations, while the lips have a remarkable development and peculiar covering, which reminds us of the first embryonic trace of the duck-like bill of Ornithorhynchus. The tongue has a peculiar papillated groove in its upper surface, and three large papillæ on its base. The larynx and epiglottis project so high into the broad pharynx that the milk swallowed has to go in two streams around it, one on either side. A very large thymus gland, having three lobes, lies above the heart. Only a rudiment of this exists in the adult. The cerebral lobes of the brain are smaller, and the optic lobes larger than in the full-grown animal. When first born, male and female are not distinguishable either from external or internal appearances. Later the marsupium begins to appear, first as a cluster of very low papillæ on the abdomen, surrounded by a very low ridge. This ridge rises higher and the depression extends itself deeper and more laterally, while the ridge becomes a fold of skin growing inwards toward the median line, until only a narrow median opening is left. Curiously the young male at first has as good a marsupium as the female, but this becomes gradually lost as it matures.

This essay was illustrated by chalk sketches and some alcoholic specimens of Ornithorhynchus, Echidna, and Opossum embryos.

Fig. 3.

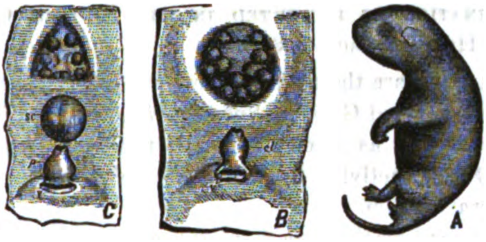


Fig. 4.

Fig. 1.

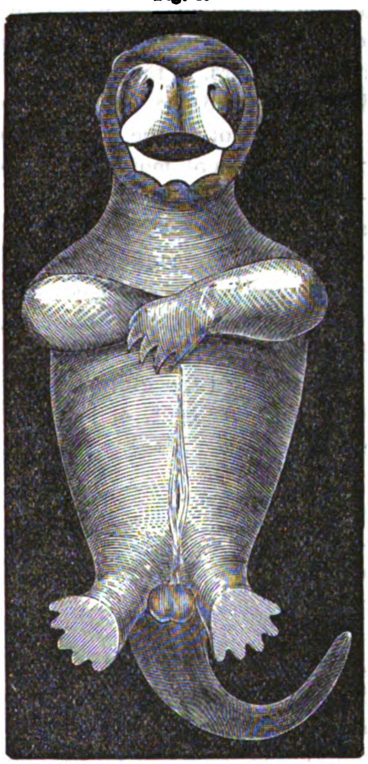


Fig. 2.

Figs. 1, 2. Front and side views of uterine Opossums (*D. Virginiana*), enlarged. Entire length when straightened out, one-half inch.

Fig. 3. A, young female Opossum (*D. Virginiana*), natural size. B, marsupium, clitoris, and vent of the same, enlarged. C, marsupium, scrotum, penis, and vent of a male of the same litter, enlarged.

Fig. 4. Young Opossum. Natural size.

On Hibernation as exhibited in the Striped Gopher. By P. R. Hoy, of Racine, Wis.

The following are the results of many observations and experiments on the Striped Gopher, *Spermophilus tridecemlineata*, during active life as well as when under the profound stupor of hibernation. During activity the Gopher's pulse is 200; respiration 50; temperature 105.

On the second of October, having procured a red squirrel, *Sciurus Hudsonicus*, and a gopher, animals of nearly equal size, the one active during the coldest weather, while the other is a characteristic hibernator, I cut out a part of the gluteal muscles of each, and after dividing and bruising, so as thoroughly to break up every part, I took fifty grains of each and placed in a test tube, into which I put two ounces of cold water. After freely agitating, the mixture was left to digest for eight hours, at the expiration of which time I carefully decanted and renewed the water, agitated and left twelve hours, then filtered and rolled the residuum on blotting paper, in order to remove all excess of moisture. When weighed they stood: gopher 50–15, squirrel 50–10. These experiments were repeated with substantially the same results. Gluteal muscles of the squirrel contained twenty per cent. of albumen, soluble in cold water, while the same muscles of the striped gopher treated in like manner, at the same time, yielded thirty per cent.

As it is well known that the flesh of reptiles is rich in albumen, I procured several marsh frogs and subjected the gluteal muscles to like analysis, which resulted in forty per cent. of loss. The following will convey to the eye these results.

Per cent. of soluble albumen—

Frog,	40.
Gopher,	30.
Squirrel,	20.

On the fifteenth of December, the gopher being thoroughly torpid, temperature of the room forty-five, gopher rolled up like a ball, no visible evidence of life, I opened the abdomen and inserted the bulb of a thermometer which indicated 58°. I next turned back the sternum in such a manner as to expose the heart and lungs. The remarkably congested condition of these organs

first attracted my attention; in fact, it would appear as if all the blood had collected within the thorax. The pulsation of the heart was reduced to four each minute, the auricles would slowly and imperfectly contract, followed immediately by the ventricles. These slow pulsations of the heart occupied four seconds. There was no visible respiration, the lungs remaining almost entirely passive. The heart continued to pulsate, without perceptible change, for fifteen minutes, and then when raised from its position it continued to pulsate for sometime, being almost reptilian in this respect. During hibernation the circulation is so feeble that when a limb is amputated but a few drops of blood will slowly ooze from the fresh wound. The stomach and bowels empty, and the body was incased in a thick adipose layer. I was not able to excite the least motion or contraction of the muscles in any way, even by pinching or cutting nerves, showing the most perfect condition of anasthesia possible.

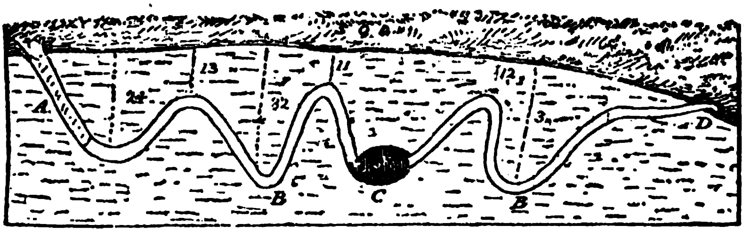
During hibernation the gopher is not able to endure more than six or eight degrees of frost. The manifestations of life are so feebly performed, that a few degrees below freezing is sufficient to convert apparent death into the reality. On the 10th day of April, at which time the first gopher appeared above ground, I repeated the experiments of the previous autumn. Body emaciated, hair dry and lifeless, flesh perceptibly less moist than it was in the fall. On subjecting the gluteal muscles to like treatment, as in October, I was surprised to find only eighteen per cent. of loss instead of the thirty, as exhibited in the previous autumn.

The large amount of soluble albumen found in the flesh of the Striped Gopher in the fall, and the lesser amount found after its protracted hibernation, go far to prove that albumen somehow fits the animal for its long sleep. Is it not probable that albumen is a stored-up magazine of elaborated nutrition to be used when no food can be assimilated by the digestive organ?

The burrow prepared by the gopher, in which to hibernate, is a fine piece of engineering. The following is a profile view of one of these retreats, explored with great care.

A sandy ridge with a more or less degree of inclination was selected. The excavation was commenced at A, where all the earth removed was deposited. The excavations at B, one on either side of the nest, were carried down thirty-two inches, the

maximum depth. C, the nest is an excavation eight inches in diameter, which is filled with dry grass; on one side of the nest was a deposit of half a pint of buckwheat, a small store, sufficient however to last five months, from November to April.



Burrow of the Striped Gopher. From A to D, twelve feet.

It is certain that no food can be taken in the stomach during the winter, only when awakening in the spring will food be required. At D there is a small hole cut through the sod, just large enough for this small animal to squeeze through, but not a particle of earth is taken out here, though it is left open. The burrow is finished by compactly filling to the depth of two feet with dirt at A. You perceive how thoroughly drained the nest is; it would be impossible to drown the occupant out, which is so easily accomplished when they take to their temporary summer retreats. There is a double purpose, it would appear, of carrying the excavation up to within a foot of the surface, in several places, to secure thereby, that cool temperature, the most congenial for the torpid state, as well as to secure drainage; for it is evident if the nest were kept too warm the animal, being only imperfectly torpid, would starve. Also the small hole left open at D, may serve partly for the same purpose as well as for its easy exit when the warm days come. These burrows contain but a single individual. I believe that never more than one gopher hibernates in the same nest.

Notes on the North American Ganoids, Amia, Lepidosteus, Acipenser and Polyodon. By Burt G. Wilder, of Ithaca, N. Y.

(With three plates.)

I.—The respiratory actions of Amia and Lepidosteus.

The respiratory actions of *Lepidosteus* have been described by Prof. L. Agassiz and by Prof. Poey. The observations of the latter (27)[1] are reproduced by Duméril (4, II, 306).

Prof. Agassiz' remarks are reported as follows:

"This fish is also remarkable for the large quantity of air which escapes from its mouth. The source of this Prof. Agassiz had not been able to determine. At certain times it approaches the surface of the water and seems to take in air, but he could not think that so large a quantity as is seen adhering in the form of bubbles to the sides of the gills, could have been swallowed, nor could he suppose that it could be secreted from the gills themselves" (2).

During the past summer the ten young *Lepidosteus* mentioned in another part of this paper, were observed by me for about three weeks. They seemed to prefer keeping near the surface, probably for convenience of aërial respiration. In emitting the bubble of air they raised the anterior end of the body a little, but I could not be sure that they intentionally protruded the head from the water. At the same moment the whole body was suddenly rolled on one side, and one or more bubbles of air escaped from the mouth. Within a second or two after assuming the horizontal position, other and smaller bubbles escaped from the opercular orifice.

With the smallest gar ($63^{mm.}$, about $2\frac{1}{2}$ in. long), these respiratory movements occurred pretty regularly at intervals of $\frac{1}{2}$ to $\frac{3}{4}$ of a minute. It rolled almost invariably upon the right side so as to emit the bubbles from the left. The ordinary branchial respiratory movements of the jaws and opercula were 95 per minute.

Very often these young individuals of *L. osseus*, and more frequently the adults of the smaller species (*L. platystomus*), would protrude the snouts from the water in the respiratory act; but the

[1] See list of works referred to, at the end of this paper. The first figure designates the number of the work on the list; the last, the page; the middle, when it occurs, the volume.

length of the jaws made it impossible to determine whether this was intentional and for the purpose of inhaling as well as of exhaling the air.

Inasmuch, however, as the exhalation could be as well accomplished at any depth, the uniform approach of the gars to the surface goes to show that air is taken in as well as given out.

More satisfactory observations upon this point were made upon adult and uninjured individuals of the mud-fish, *Amia*, which, like *Lepidosteus* has a very cellular and vascular air-bladder with large air-duct, and upon the respiratory actions of which nothing has been published so far as I am aware.

Amia seems to prefer the darker parts of the aquarium and to remain at or near the bottom, but like *Lepidosteus* it comes to the surface at intervals to breathe. One or two very large bubbles of air escape from the mouth, and on descending, some lesser ones from the operculum.

When at the surface the movement of the jaws seemed to be two-fold, first to permit the escape of air, and second to take in a fresh supply. But the whole was so rapidly executed that I could not be certain.

The following method was adopted for determining this point.

The fish was gradually accustomed to the contact of the hand, gently embracing the body at about the middle. After a time it would swim slowly in the tank with no apparent agitation on account of the contact, and come to the surface at the usual intervals to discharge a bubble of air.

Having been thus prepared, the fish was permitted to move to and fro at about six inches below the surface, but prevented from rising. It became uneasy and after a few not very violent efforts to disengage itself, emitted a large bubble of air which rose to the surface.

If this emission were all it required we may suppose that it would have been content. On the contrary, after a second or two of quiet (perhaps resulting from the habit of being satisfied after the respiratory action), the fish became more and more uneasy; moved rapidly to and fro, turned and twisted, and lashed with its tail, and finally escaped from the hand. It rose at once to the surface, and, *without emitting any bubble whatever*, *opened the jaws widely and apparently gulped in a large quantity of air*. It then

descended and remained quiet for the usual interval. This experiment was several times repeated, always with the same result.

There seems no doubt from the above, that with *Amia* there is a true inspiration as well as expiration of air. The same may be considered probable though not yet proved, with *Lepidosteus*. The escaping air should be chemically examined. But there can be little doubt that in these two genera, in *Polypterus*, and in the Dipnoans, all having cellular and vascular air-bladders, there is effected an interchange of oxygen and carbonic acid, as in the lungs of aërial Vertebrates.

Amia and *Lepidosteus* have no spiracle and it is small in *Polypterus*. The three genera have the space between the rami of the lower jaw occupied (by plates or folds of skin with underlying muscle) so as to better prevent the egress of air than would be the case with most Teleosts. But, as already stated, some air escapes from the opercular orifice of *Amia* and *Lepidosteus* after the fish has descended, and while, probably, the air is being forced backward so as to enter the air-duct.

Amia and *Lepidosteus* were observed to perform the acts of respiration above described more frequently when the water was foul or had not been changed.

It was noticeable that they survived removal from the water for a much longer time than *Acipenser* or *Polyodon*, whose air-bladders are simple and but slightly vascular.

II.—The transformations of the tail of the gar-pike, *Lepidosteus*.

That the tail of the young *Lepidosteus* is unlike that of the adult has been observed by Prof. Louis Agassiz. But although he repeatedly called attention to the transformation, little notice has been taken of it; it is not mentioned in any systematic work in the English language.

This neglect may have been due partly to the absence of figures from Prof. Agassiz's descriptions, and partly to their brief and, to some extent, contradictory nature.

The observations of Prof. Agassiz are here reproduced.

"Zadock Thompson has described a young specimen under the name of *Lepidosteus lineatus*. . . . . I have ascertained, by a series of specimens, that the detached lobe formed by the upper

raylets of the caudal fin is gradually united with the lower rays," (Agassiz, 1, 263.)

"In the immature state these fishes [the species of *Lepidosteus*] have the upper region of the caudal separate from the lower as a distinct lobe, the body is scaleless, and the pectorals consist of membrane arising from a fleshy tubercle; . . . . they have mostly a broad longitudinal black band along the middle line," (Agassiz, 9, 360.)

"The young gar-pikes are remarkable as possessing certain embryological characters. The most conspicuous of these is the prolongation of the vertebral column in the shape of a fleshy filament, distinct from the caudal fin, which [the filament] had at times a vibratory motion, involuntary, and quite distinct from the motions of the body itself, as is seen in some embryos."

"This singular formation shows that the caudal fin is properly an appendage to the lower surface of the dorsal column, a true second anal, and not the proper termination of the column." (Agassiz, 2, 48.)

It will be noted that in this later account Prof. Agassiz speaks of the filament as *single* and not as the upper raylets, as in the passage first quoted. But he does not here correct the erroneous statement, that it is "gradually united with the lower rays."

"In the adult state, the *Lepidosteus* has a large rounded caudal at the extremity of the tail; in the young, the entire caudal is placed below the extremity of the vertebral column, as a second anal, and the vertebral column is prolonged as a detached lobe, along the superior border of the caudal. That conformation persists until the fish is .200, (2 decimeters, about 8 inches) in length." (Agassiz, 3, 57.)

Dumeril (4, 319) calls attention to these descriptions by Agassiz, and figures (Pl. 24, fig. 4) the tail of what is stated to be a very small specimen, but which, judging from the size of the figure and the shortness of the filament, was probably at least 200$^{mm.}$ (about 8 inches) long.

My own observations relate to the form of the tail in the very young, before it assumed the character described by Agassiz; the manner of formation of the caudal fin; the gradual disappearance of the filamentary end of the body; its representation in the tail of the adult fish.

The material at my disposal is as follows :—

A. Young *Lepidosteus* brought to me in alcohol by Master Edward Steers (nephew of the late Prof. Evans of Cornell University), who took them from the Red River, near Shreveport, La.[2]

The smallest of these is shown (enlarged 5 diameters) in fig. 1. It is 18 millimeters (about ¾ of an inch) long. The largest is $44^{mm.}$ (about 1¾ inches) long.

B. Ten young *Lepidosteus* (probably *L. osseus*) obtained by me in the Illinois River, at Peoria, during July, 1875. These were kept alive by me and carefully watched for from three weeks to a few days each. The smallest is $63^{mm.}$ (about two and a half inches) long; the largest is $300^{mm.}$ (about twelve inches) long.

C. Numerous specimens and preparations of adult and partly grown *L. osseus* and *L. platystomus* in the Museum of the Cornell University.

The smallest *Lepidosteus* in my possession (it is apparently much smaller than any that have hitherto been examined) is $18^{mm.}$ (a little less than three-fourths of an inch) in length. In figure 1 it is enlarged 5 diameters. Unlike most young specimens it is almost colorless.[3]

The head is rather short and depressed like that of *Polypterus*. The eyes are large and dark. The nostrils are easily seen; the anterior openings look upward and outward instead of downward and forward as in the adult. The branchiostegal membranes are separate as far forward as the transverse fold which exists in all *Lepidosteus*.[4]

The ventral fins have not yet appeared. The pectorals are very large and prominent, and consist of a central lobe with a thin border or fringe. The significance of this will be discussed hereafter; see page 166.

A median fin extends from the middle of the length to the vent,

[2] Several of these were handed by me to the late Prof. Agassiz. Unfortunately his failing health and pressing avocations prevented any examination of them, and they have been kindly loaned to me by Mr. Alex. Agassiz, Curator of the Museum of Comparative Zoology.

[3] This is the case with two small specimens about $5^{mm.}$ long, taken from the stomach of a small *Lepidosteus*. They are probably newly hatched gars, but are not capable of determination.

[4] I think there are reasons for regarding this fold as homologous with the hinder border of the gular plate of *Amia*. But as this question involves the homology of some other parts now undetermined, I reserve it for another occasion.

and thence to the end of the tail. A similar primordial fin extends along the hinder third of the body above. This fin is quite deep and consists of a delicate membrane supported by very numerous and slender rays in close apposition; they incline slightly backward.

The tip of the tail is unfortunately missing from this specimen, so that its exact form can only be inferred. The larger specimens show a gradual sharpening of the caudal extremity, whence we may infer that in the earliest stage the end is not very acute.

Near its hinder extremity the body has a slight *downward* inclination. In all the larger individuals the body is either nearly horizontal or inclined upward at its hinder extremity.

The primordial median fin presents four points of special alteration, two dorsal and two ventral. They are nearly opposite each other, but the ventral one of each pair is a little anterior to the dorsal.

They appear to be somewhat thicker than the surrounding parts of the fin, and darker from a greater or less deposition of pigment granules, especially near the margin of the body.

The anterior pair (*D*, *A*), dorsal and ventral, occupy the portion of the dorsal and anal fins of the adult. But no large rays, or other structures than the delicate rays of the primordial fin, are to be seen.

The hinder dorsal spot (*X*) is very faint and would hardly be noticeable but for its more pronounced character in larger specimens. It has no large rays and later disappears entirely.[5] It may possibly represent the second dorsal of *Glyptolæmus;* but more probably the upper lobe of the caudal fin of *Undina* and *Macropoma*. This correspondence will be referred to hereafter.

The spot (*C*) on the lower lobe of the caudal of the young *Lepidosteus* is evidently a developing fin. It is thicker than the rest of the primordial fin. In the centre of the thickened space are dimly seen four or five larger rays pointing obliquely downward and backward. Their attachment to the margin of the body is indicated by its thickening and by a crescentic emargination. This emargination resembles that on the lower part of the tail of *Calamoichthys;* but in this genus the fin so indicated is probably the true anal; the infra-caudal lobe not being differentiated.

[5] This transitory fin is comparable with the temporary anals of the young skate as described by Wyman (11, 35); one of which, however, attains quite a large size before its disappearance.

The specimen above described, represents, so far as I am aware, the earliest known stage of *Lepidosteus*. But there can be no doubt that at a still earlier stage the tail was simple and undifferentiated like that of *Amphioxus*.

A second very small specimen is no longer than the one above described, but seems to be more developed. It is darker colored; the belly being almost black while the upper half of the body is brownish. The four median fins are indicated by decided though irregular blotches, and the rays of the infra-caudal are more distinct.

White longitudinal elevations show where the ventral fins (*Ve*) are about to appear.

The difference in the color of these two smallest specimens is very marked. The white one is apparently the younger although a trifle the longer. But it cannot be determined at present that the color is developed only after the attainment of a certain size or stage of growth.

The specimen next figured (Fig. 2) presents the following features. Its length is $23^{mm.}$ Its colors are darker than the one first described, but less decided than in the second small specimen referred to.

The ventral fins (*Ve*) are little white buds opposite the anterior extremity of the primordial fin (1). This latter has changed but little. It seems rather thinner and its borders are ragged, as if in process of removal by both absorption and abrasion.

In addition to the interruption for the vent, the primordial fin now presents three emarginations, as follows: — 1. About mid-way between the spots representing the dorsal and the supra-caudal fins. 2. Behind the spot representing the anal fin. 3. Between the primordial fin (3) on the lower border of the tail and the infra-caudal lobe, which now projects slightly and is supported by eight or ten rays split at their tips but reaching the border of the fin.

In this specimen we see the beginning of the changes which are to result in the total disappearance of the tail proper and the taking of its place and office by the greatly enlarged infra-caudal lobe.

Passing over intermediate sizes in which the head is progressively lengthened, and the ventrals enlarged we come to the specimen represented in fig. 3.

Like the one first described this is a pale individual. Its total length is $44^{mm.}$ From the tip of the snout to the middle of the eye, $9^{mm.}$; from the eye to the vent, $21^{mm.}$; from the vent to the tip of the tail $14^{mm.}$

The primordial fin has disappeared excepting on the border of the filament (*fl*) which is the elongated and slender termination of the body. The pectoral fins are still distinctly lobate, the thin border not being more than one-half as broad as the fleshy central lobe.

The anal and dorsal fins are distinct, and have each seven rays. The ventrals are still very small.

The rays of the infra-caudal are distinct. They are more nearly in line with the body than in the younger specimens, while the tail is slightly elevated. Both the filament and the infra-caudal lobe have increased in length. But the latter has also become wider, while the former is so slender as to merit the name filament. It projects about $1.5^{mm.}$ beyond the infra-caudal lobe.

The specimen last described is the largest of those from the Red River. The smallest of the specimens from the Illinois River has a total length of $63^{mm.}$; $13^{mm.}$ from muzzle to middle of eye; $28^{mm.}$ from eye to vent, and $22^{mm.}$ from vent to tip of filament.

As in most of the Red River specimens and all of those from the Illinois, the dark lateral stripe is strongly contrasted with the white belly and brownish back. The border of the pectoral is now equal to the lobe. The tip of the caudal filament is very slender and projects $3^{mm.}$ beyond the infra-caudal lobe.

At the base of the filament, just behind the tip of the dorsal, are two pairs of slight elevations, one behind the other, and looking backward. These are the first representatives of the *fulcra;* a series of strong spine-like plates which, in the adult gar, cover the anterior part of the upper and lower borders of the tail.

In a specimen $108^{mm.}$ long, the tips of the filament and the infra-caudal lobe coincide. Both have increased in length and width, but the lobe more rapidly than the filament.

The outlines of scales appear on the sides of the hinder half of the body, and there is an increase in the size and number of the fulcra.

In a specimen measuring $142^{mm.}$ from tip of head to tip of caudal lobe, this latter projects $8^{mm.}$ beyond the filament. Its rays, that is, the central ones, are in direct line with the axis of the body,

while the base of the filament is crowded upward. There are now five pairs of fulcra, the hindermost of which extends backward as far as the point of separation between the filament and the lobe. Behind this point the filament is apparently undergoing structural degeneration and removal. It is thin, slender and ragged at the edges.

But there is evidently considerable variation as to the period of this removal. For of two specimens about $190^{mm.}$ in length, one has the filament equal to the lobe, and in the other it is but $3^{mm.}$ shorter.

The largest specimen in which the filament is preserved, is about $300^{mm.}$ long. The lobe projects $15^{mm.}$ beyond the filament. The free part of the latter is much attenuated, and, during life, was but feebly and occasionally employed. The tail of this specimen is shown in fig. 4.

In imagination we may readily supply the stages intermediate between that last described and the tail as usually represented, where the free part of the filament has wholly disappeared, and its base, covered by the fulcra, seems to form only the upper border of the functional tail. This latter, however, from a morphological point of view, is really an appendage of the filament.

The movements of the filament have been well described by Agassiz. He, however (2), speaks of it as "involuntary." By this he may have meant only that, as with other very rapid vibrations, a separate volition is not required for each individual movement. In fact, during vibration, the filament is invisible. But the motion is not involuntary as is that of cilia or unstriped muscular fibres. For at times the filament is wholly at rest; it may be elevated or depressed, curved strongly to the one side or to the other, and more or less rapidly vibrated in any of these positions.

The movement may be compared to that of the wings of most insects and of the humming-bird. Still more closely with that of the tail of *Crotalus*.[6]

On each side of the cartilaginous rod, in its whole length, is a band of *striated* muscular fibre.

It would be interesting to ascertain whether the nervous supply comes from the cord within the filament or from the permanent

[6] Many of the *Colubridæ*, under strong excitement, will vibrate the tail as does the rattlesnake.

portion of the cord anterior to the point of its separation from the infra-caudal lobe.

The representation of the filament in the adult tail. Agassiz' figure of the tail of *Lepidosteus* (5, tome II, tab. A), was probably made from a dry preparation, and his description (tome I, part II, 23), does not mention any cartilaginous prolongation of the bony vertebral column. I am not aware of any other figures or description of the tail of *Lepidosteus*.

Figure 5 represents (reduced ½) the dissected tail of a medium sized *L. platystomus*. It will be noted that the outline of the caudal fin (the infra-caudal lobe of the foregoing descriptions) is nearly though not quite symmetrical; the lower rays being a little shorter than the uppermost.

In the figures of Agassiz and Duméril the outline is much more oblique. This however, may be due in part to the fact that the upper rays are usually less separated than the lower, so as to cover less area than the lower.

Probably too, there is specific variation in this respect. I am inclined to think also that the same species presents different characters at different ages. But for the determination of these questions a large number of individuals should be compared after their species have been ascertained. At present the taxonomy of *Lepidosteus* is in a very confused state.[7]

The outline of the base of the fin presents a double curve like an elongated letter *f*. The fulcra cover the anterior two-thirds of the dorsal border and three-fourths of the ventral border. Both series are closely attached to the uppermost and lowermost caudal ray respectively. These rays not only divide and subdivide like the fin rays of *Malacopteri*, but also consist of two lateral halves[8] which are often not exactly applied to each other, as seen in fig. 6.

The lateral halves of the uppermost caudal ray are separated from each other excepting at their lower border, and between them lies a tapering cartilaginous rod, whose upper surface is covered by the bases of the dorsal fulcra. The relation of parts

[7] The same is true of many other American forms which are not readily obtainable, in large numbers, by European naturalists; as, for instance, the American Sturgeons, the Petromyzontidæ, and the tailed Batrachians.

[8] Goodsir (13, II, 106) and Humphrey (8, 59) have called attention to the fact that the rays of median fins consist of two lateral halves. The latter author regards it as one of the grounds for considering each lateral fin to correspond to a lateral factor of a median fin. I find, however, that in *Lepidosteus* the rays of the ventral fins are likewise double.

is seen in fig. 6, which represents a vertical section of the upper border of the tail about the middle of the series of fulcra.

Posteriorly the rod may be traced to beneath the hindermost fulcra, this point corresponding nearly with the point of separation of the filament and infra-caudal lobe in the young. Anteriorly it descends gradually to become continuous with the hindermost vertebra.

The cartilaginous rod above described is called notochord by Huxley (7, 20). A cross-section, however, shows that it really represents the whole spinal axis, as seen in fig. 6. The notochord (*N*) is surrounded below and on the sides by the cartilaginous and unsegmented basis of the vertebræ (*CS*) which, above, separates into two laminæ enclosing the neural canal and the spinal cord (*SC*).

The structures above described are readily seen in the tail of the adult *Acipenser* and *Polyodon*. After maceration in weak spirits for some months, the notochord of these genera may be withdrawn from the surrounding cartilage as a membraneous tube, the contents of which may be washed out.

In *Polyodon* the fibres of this membraneous notochordal sheath are arranged in a peculiar net-work permitting considerable extension, with contraction of the caliber, or shortening with corresponding increase in diameter.

In *Amia* the cartilaginous sheath is thicker in proportion, but the true notochord and the spinal cord may be traced to the extremity.

The whole structure is much shorter than that of *Lepidosteus*, but in several specimens prepared by me, it comes much nearer the upper border of the fin than in the figure by Huxley, (7, fig. 6). The rod is not represented by Franque (10).

The tail of the adult *Amia* has, therefore, essentially the same structure as has that of *Lepidosteus*. Nothing is as yet known of the earlier stages of its development. Through the kindness of Prof. H. A. Ward, of Rochester, I have recently obtained two small specimens, respectively $70^{mm.}$ and $100^{mm.}$ (about three and four inches) long, which have the characteristic tail of the adult[9]

[9] These specimens will be described upon another occasion. For the present I will only mention that in both the markings on the body and fins are more distinct than in the adult, and that the smallest presents two decided black stripes on each side of the head, one of which runs across the eye, as in the young *Lepidosteus*, while the other descends obliquely backward from the eye toward the margin of the operculum.

with an even more decided upward inclination of the upper caudal rays, in strong contrast with the figures of Franque (10) and Huxley, (7, Fig. 6).

Nevertheless, so nearly does the tail of the adult *Amia* resemble that of *Lepidosteus*, that I cannot avoid inferring that it passes through a similar series of transformations. And I would suggest to those who live near the breeding places of *Amia*, the importance of making a complete study of its development.

As the most teleosteoid of Ganoids (its ganoid nature being in fact denied by Lütken, 16, 336), its embryology will be especially valuable.

The stages through which the *Lepidosteus* passes are comparable with the adult conditions of various living and fossil forms.

But this parallelism is rarely or never exact in regard to more than one of the features under consideration, the direction of the spinal axis and the subdivision of the primordial median fin.

As already stated the first stage is not represented among the specimens. But, judging from all analogy, we may infer that the young *Lepidosteus* of about $10^{mm.}$ in length, has a continuous median fin with no differentiation of color or thickness, and with no sign of subdivision into separate fins; and that the posterior end of the body is horizontal or slightly deflected downward, separating the equal or nearly equal upper and lower caudal lobes.

In the earliest of the stages here described the spinal axis is still nearly horizontal, but the median fin shows signs of subdivision.

In both the tail would be described as truly homocercal by most authors, as diphycercal by McCoy and Huxley, and as protocercal by Wyman.

I do not wish, on this occasion, to discuss the general subject of the nomenclature of tails. But it seems to me that all the arguments of Huxley in favor of diphycercal for homocercal[10] as applied to tails like that of *Polypterus*, apply with even greater force toward substituting protocercal for both. For the latter term indicates that the structure under consideration exists in the earliest known stages of development of Selachians and Ganoids;

[10] Cope (17) has proposed "isocercal" for the same form of tail. But he applies this term to the eel (*Anguilla*), in which, according to Huxley (15, 42), the arrangement is really heterocercal as in most if not all other osseous fishes. The whole subject, however, needs a special revision by comparison of several stages of development of the tail in all forms of aquatic vertebrates.

in certain very ancient Ganoids (as *Glyptolœmus* and *Gyroptychius*); and in the generalized forms *Lepidosiren* and *Ceratodus*.

I have not been able, however, to find the word used elsewhere than in Wyman's paper on the Development of *Raia batis* (11).

Upon the general subject see Huxley (6, 7, and 15), with other papers therein referred to.

This stage of the *Lepidosteus* may be compared with *Amphioxus*, the lowest known Vertebrate, with *Lepidosiren*, *Protopterus* and *Ceratodus*,[11] where, however, the primordial fin-rays seem to have been replaced by stronger and permanent rays; *Myxine*, *Bdellostoma* and *Petromyzon*, where the rays are cartilaginous;[12] (in some species of *Petromyzon* the median fin is continuous, with slight undulations indicating the subdivisions in other species); and with *Menobranchus* and *Menopoma*, where, as in the larvæ of Anoura, there are no fin-rays at all.

The cartilaginous prolongation of the vertebral column of *Polypterus* is not shown by Agassiz (5, II, tab. C). It is figured by Huxley and described (7, 20), as hardly at all bent up.

In a *Calamoichthys* in my possession a line drawn vertically across the tail over the end of the cartilaginous rod intersects twelve fin-rays. Four of these lie above the rod and eight below. Still the upward inclination of the rod is very slight, perhaps not enough to prevent the recognition of these two genera as protocercal. Some other form would have been better, however, for illustration.

Among fossil forms with apparently protocercal tails are probably included the extinct species of *Ceratodus* described by Newberry and Cope.

In all the above excepting *Polypterus* and *Calamoichthys*, the median fin is continuous as if formed by direct enlargement of the whole primordial fin.

But in other fossil forms, as in the two genera above named, parts of the primordial fin are differentiated and bear the names dorsal and anal.

The most instructive of these is *Glyptolœmus*, a Devonian fish described and figured by Huxley (6, fig. 1, and plates I and II). "There are two dorsal fins placed in the posterior half of the

[11] Commonly known as Dipnoans, but included among the Ganoids by Günther (19) Gill (12) and others.

[12] Perfectly distinct, although these have been called Dermopteri by Owen.

body. The ventral fins are situated under the first dorsal and are succeeded by a single anal. The caudal fin, whose contour is rhomboidal, is divided into two equal lobes by the prolonged conical termination of the body; in other words, the fish is diphycercal or truly homocercal" (Huxley 6, 3).

Huxley states that the head, body and fin, of *Gyroptychius* might be described in the terms which have just been applied to *Glyptolœmus*.

Both these genera are comparable with the first stage of *Lepidosteus*. The tail is strictly protocercal (or "diphycercal"). Moreover there are two dorsals. If the anterior be the homologue of the single dorsal of the adult *Lepidosteus*, then the posterior may, perhaps, represent a development of the transitory posterior dorsal of the young *Lepidosteus*. If the anals correspond in the two, then the infra-caudal lobe of *Lepidosteus* is not differentiated from the rest of the tail in *Glyptolœmus*, or *Gyroptychius*.

But it may be that another interpretation is more nearly correct. Certain other fossil forms, as *Undina*, and probably *Macropoma*, have a continuation of the vertebral column between the two equal lobes of the caudal fin, and the prolongation of the caudal extremity beyond it as a filamentary appendage (Huxley 6, 15). Leaving out of the comparison the advanced anterior dorsal of *Undina*, the posterior dorsal may be compared with the true dorsal of *Lepidosteus*; the anals are apparently homologous. There are then an upper and a lower caudal lobe of nearly equal size, the filament projecting between. The lower lobe may naturally be homologized with the permanent infra-caudal of *Lepidosteus*, while the upper lobe represents a similar development of the transitory appearance (*X*) of *Lepidosteus*.

Which of these interpretations is correct will hardly be determined before the general affinities of all these forms, fossil and living, are better understood than at present. Meantime I venture to call attention to the facts, well known but not always borne in mind, that all median fins are differentiations of a single continuous primordial fold; that even in nearly allied forms they present considerable diversity of size and position; and that no such taxonomic significance is probably to be assigned to them as to the lateral fins, of which there are never more than two pair.

Leaving out of the comparison the degree of subdivision of the median fin, the stages 3, 4, and 5, represented in figs 2, 3, and 4,

have their more or less accurate counterparts among various living and fossil Ganoids and Sharks.[13]

Alopias has a long upper lobe (so-called).[14]

In *Polyodon* and some species of *Acipenser* and in most Sharks, the upper lobe is but little the longer; in *Lamna* the lower lobe nearly equals the upper. I am not acquainted with any Ganoid or Selachian where the lower lobe is the longer, as in the sixth stage of *Lepidosteus* (Fig. 5).[15]

The last stage (7, fig. 6), exists in *Amia* alone among living Ganoids, and, so far as I am aware, is not presented by any palæozoic forms; their tails being either protocercal (as in *Glyptolæmus*) or obviously heterocercal as in *Palæoniscus*, etc.

But among mesozoic forms the amioid tail is not unusual; and a series may easily be formed, as, for instance, of *Lepidotus*, *Megalurus* and *Thrissops* by which the truly heterocercal tail is apparently converted into the apparently homocercal form. Indeed the tail of *Megalurus*, as figured by Agassiz (5, tab. E, fig. 4), might almost be taken for that of *Amia*.[16]

[13] Several species of *Loricaria* have the upper caudal ray greatly prolonged so as to form a filament. In an adult examined by me there is no prolongation with it of the notochord. It would be interesting to examine the young in this genus. The filament adds another to the analogies between the Goniodonts of South America and the Sturgeons of the Northern hemisphere which have been pointed out by Agassiz (20, 30; 21, 242, 299; 22, 354).

[14] I use the term upper lobe because it is commonly employed. Strictly speaking, however, it is not a lobe of the caudal fin in any such sense as is the lower lobe here called infra-caudal. It is the prolongation of the body and is really a gigantic *filament*. The tail of *Chimera* is even more exaggerated.

Something like a reversed representation of the changes in the tail of *Lepidosteus* occurs with the developing skate. The dorsals of *Raia batis* were found by Wyman (11, 43) to "change position from the middle to the end of the tail. At the time of hatching, however, there is still a slender terminal portion of the tail which is afterwards either absorbed or covered up by the enlarged dorsals as they extend backward."

In a young skate taken from the egg-case and measuring 70mm. in length, I find projecting beyond the second dorsal a slender filament about 10mm. long, which is atrophied as compared with the rest of the tail, and apparently in process of removal. (In *Uraptera*, as remarked by Wyman, this slender tail is persistent). After its removal the hinder dorsal of the skate occupies toward the end of the body the same position, morphologically, as if it were a supra-caudal lobe or differentiation of the primordial fin, corresponding to the infra-caudal lobe of Lepidosteus. The end of the vertebral column is not, however, bent downward so as to allow the dorsal to be strictly terminal: perhaps in adaptation to its frequenting the bottom.

[15] There seems to be no reason why such a form should not exist, a reversed counterpart of *Alopias* as *Hemirhamphus* is of *Xiphias*.

[16] In the diagrammatic restoration of *Megalurus* above referred to, the scales are represented as rhombic. But they are really cycloid, as in *Amia*, in all the four species shown by Agassiz in Plates 51 and 51a of the same work. May not *Megalurus* be a fossil representative of the Amiadæ? Huxley, however, (7, 127), says that "it is not certain that any member of the group occurs in a fossil state;" and Lütken (16, 336), thinks "there is no positive reason for arranging the Megaluri (which he regards as Teleostei) with the Amiadæ."

Since Huxley (15) has shown the probability that the tails of most if not all Teleostei, are really strongly heterocercal, it is not difficult to imagine a series by which the tail of *Amia* should become that of one of the Clupeoids with which Cuvier had placed it. Indeed there are fossil Ganoids (*Thrissops*, *Aspidorhynchus*, etc.) whose tails are apparently as perfectly homocercal as those of any *Salmo* or *Scomber*, but which, by analogy, we may suppose to have been, in the earlier stages of development, distinctly heterocercal, or, perhaps, even protocercal.

But the transition is still better illustrated by the changes which occur in *Gasterosteus* as described by Huxley (15) and as lately seen by me in a Siluroid.

For in the young *Gasterosteus* the cartilaginous rod (called notochord by Huxley) is not only strongly bent upward but also reaches the upper angle of the tail, nearly as in *Lepidosteus*. But in the half-grown fish, by the growth of the fin rays the end of the notochord "no longer reaches, by a long way, to the posterior superior angle of the caudal fin;" this is the condition of things in *Amia*.

It may be said, therefore, that the Teleostean tail does not simply begin where the Ganoid tail leaves off, but actually overlaps it; the two earlier stages of the former being represented by the tails of *Lepidosteus* and *Amia*, the latter genus, as has been already stated, being regarded as the most teleosteoid of Ganoids.

Lütken has remarked (16, 332) that "in general an evident progress from the heterocercal to the so-called homocercal or fan-like tail may be observed running parallel to the progress of the geological epochs."

The transformation of the tail of *Lepidosteus* so far as already known, would have furnished an embryological parallel to the structural and geological series; while the earlier condition here first described enables us to extend the comparison to the protocercal forms of which some are among the oldest known fishes and others, now living, are either the lowest of vertebrates or manifest such striking relations with other classes as to have received the name "generalized Ganoids."

III.—The transformations of the pectoral fins of Amia and Lepidosteus.

Rafinesque[17] described a small gar-pike under the name *Sarchi-*

[17] Journ. ac. nat. sci., Philad., 1818, vol. I, part II, p. 418.

rus because the pectorals consisted of a membrane rising from a fleshy lobe.

Agassiz (9, 360; 3, 58) has shown that this form of pectoral is characteristic of the young *Lepidosteus*. Duméril (4, 320) quotes Agassiz' observations but makes no comment upon them. No other systematic work, so far as I know, contains any reference to the fact.

Since Huxley (6, 24), has proposed a new sub-order of Ganoids, Crossopterygia, mainly "in consideration of the peculiar manner in which the fin rays of the paired fins (the pectorals and usually the ventrals) are arranged so as to form a fringe round a central lobe," it is desirable to ascertain whether the early stages of other Ganoids exhibit similar features.

This is certainly the case with all the young *Lepidosteus* above described, including the largest. Moreover, in any minute description of the adult *L. platystomus*, the pectoral fins would be distinguished from the ventrals by the existence of a decided fleshy rounded lobe at their base.

In the smallest gar (Fig. 1, P) the fringe forms little more than one-third the whole length of the fin. As the fish grows the lobe becomes rather longer and narrower, but the fringe increases so much more rapidly as to render the former comparatively inconspicuous in the adult.

The pectorals of *Amia*, even the adult, have a fleshy lobe. In the smallest specimen already alluded to, the length of the whole fin is $10^{mm.}$ and the basal lobe forms one-fifth of this, $2^{mm.}$

So far as regards external form alone, both *Amia* and *Lepidosteus* must be regarded as having lobate or fringed pectoral fins.

But the significance of this fact depends largely upon two other considerations. 1. Is the structure of the fin identical with that of *Polypterus* and the other forms included among the Crossopterygia? 2. Is the lobe necessarily covered by scales?

It is so covered in *Polypterus* and, as I infer, in the fossil genera. But I have not found scales upon the lobe in even the adult *Amia* and *Lepidosteus*.

Since, however, all those forms, like the young *Lepidosteus*, were probably scaleless when young, it would seem that not much weight should be assigned to the lack of scales in the adult.

IV.—On the brains of Amia, Lepidosteus, Acipenser and Polyodon.

There is a wide difference of opinion among zoölogists respecting the limits of the group commonly known as Ganoids, and its relations with the other fishes, and the higher Vertebrates. To the group as originally defined by Agassiz and Müller, including, with many fossil forms, the living *Lepidosteus*, *Polypterus* and sturgeons (*Acipenser*, *Scaphyrhynchus* and *Polyodon*), *Amia* was soon added, and Agassiz was even inclined to adjoin the Siluroids, the Plectognaths and Lophobranchs. Prof. Gill (12) considers that "the Polypterids (Crossopterygia of Huxley) and Dipnoans" (*Lepidosiren*, *Protopterus* and, probably, *Ceratodus*) exhibit so many characters in common that they are not even entitled to sub-classical distinction. Dr. Gunther (19) considers the Dipnoi as a sub-order of Ganoids, and unites these with the Selachians as a sub-class of fishes, Palæichthyes. Lütken (16) goes to the other extreme and excludes from the Ganoids not only the sturgeons but also *Amia*.[18] Cope (17, 582) does not recognize the group at all.

It will be observed that, for determining the limits and relations of Ganoids, naturalists have appealed to the scales, to the dermal ossifications upon the head, to the skull and skeleton in general, to the limbs, to the spiral intestinal valve, and the multivalvular and rhythmically contractile bulbus arteriosus.

The embryology of the typical Ganoids is wholly unknown, and this most valuable aid in classification is, therefore, not at present available.

The only brain character which has entered into the discussion is the chiasma of the optic nerves. In this the Ganoids differ from the Teleosts and Myzonts, and agree with the Selachians and higher Vertebrates; but the general aspect of the brain is more nearly that of the Teleosts.

It does not appear however that any detailed comparisons have been made between the brains of Ganoids and those of other fishes and the higher Vertebrates; and Prof. Gill who alludes (12) to "the superior taxonomic value of modifications of the brain and

[18] Lütken makes no reference to the brain, and his characters seem to be in other respects defective. But (p. 336) he admits the possibility that future discoveries may some day demonstrate to us unknown bonds.

heart in other classes of Vertebrates," does not refer to any other feature than the optic chiasma already mentioned.

Having reasons,[19] other than those derived from the extreme diversity of conclusions already referred to, for believing that a careful study of their brains will throw light upon the limits and classification of Ganoids, I have this summer (1875) made numerous preparations of the brains of the four American genera, *Amia*, *Lepidosteus*, *Acipenser* and *Polyodon*, comparing them with each other and with the figures and descriptions of Ganoid brains to which I have had access.

Since, in comparison with the preparations, none of the published figures and descriptions are wholly satisfactory, I here refer to them in detail.

Apparently the earliest figure of a ganoid brain is that by Stannius (32) of the sturgeon's brain. It seems to be a correct representation, and fairly indicates the features, which, according to the views I have reached, are characteristic of the brains of all Ganoids. But no especial attention is drawn to them, and the nomenclature of the two anterior pairs of lobes has not been accepted by later authors. Stannius calls the first pair, from which arise the olfactory nerves, the *olfactory tubercles*, and the second pair, which most authors call hemispheres (but which I believe to be specially developed portions of the thalami), the *olfactory lobes*. He thus recognizes no cerebral hemispheres at all, and makes no comparison between the sturgeon's brain and those of other fishes, or the higher Vertebrates.

It is to be noted that this nomenclature of the two anterior pairs of lobes corresponds with that which Gottsche had applied to the brains of osseous fishes, in 1835. This author (30, 445) enumerates the various names which had been given to the hinder and larger pair, and concludes that they are the olfactory lobes, the anterior pair being olfactory tubercles. Gottsche cites Desmoulins and Serres as regarding the so-called olfactory lobes as cerebral lobes, which name has since been more commonly employed. Gottsche makes no definite allusion to the brains of other fishes than the Teleosts.

[19] Based upon the probability that such an organ as the brain would be most exempt from modifications by external agencies in the progress of evolution, and would thus manifest more uniformity of structure throughout the more comprehensive groups than would the digestive organs, the skeleton or limbs. Compare Agassiz, 49, II, 362).

In 1844 Johannes Müller figured (18) the brain of *Polypterus* from above, from below, from the side and in single cross section, through the pair of lobes next to the anterior.

There can be no better illustration of the slight importance ascribed at that time to the brain for taxonomic purposes than the insufficient of figures and very brief descriptions, which the great ichthyologist devoted to the brain of a typical Ganoid. He says (p. 139) "Das Gehirn der Ganoiden ist eigenthumlich und unterscheidet sich von dem der Knochenfische und Plagiostomen." Yet his description of the brain (p. 140) and résumé of the characters (p. 141) give us only the optic chiasma, a feature which the Plagiostomes share with the Ganoids. (See also 41, 24.)

Müller enumerates the cerebellum and the optic lobes, the "lobus ventriculi tertii" (corresponding to the thalamus of higher vertebrates) the hemispheres, olfactory lobes and olfactory nerves. Although commenting upon the general resemblance of the brain to that of the sturgeon he does not call attention to the different determination which he makes of the two anterior pairs of lobes.

In the following year Busch (29) published figures of several Ganoid brains.

This work I have not been able to obtain. But if the figures of the brains of the sturgeon and the *Chimera*, copied by Owen (24, I, figs. 178 and 179), are fair examples, the work did not materially advance the knowledge of either the form, the structure, or the homology of the ganoid brain.

The paper of Hollard (34) admits three types of brains, the *teleostean*, the *plagiostome* and the *cyclostome*. It is not clear to which of these types he would refer the ganoid brain.

In 1848, a pupil of Müller, H. Franque, figured (10) the brain of *Amia* from above and below with separate views of the optic chiasma. He makes no comparisons with other brains, and his description is a simple enumeration of the lobes according to the usual nomenclature, the two anterior pairs being olfactory lobes and hemispheres respectively.

Duméril (4, pl. 20), copies from Phillippeaux and Vulpian figures of a sturgeon's brain from above and below. He makes no original observations. The so-called hemispheres are shown as solid rounded masses without eversion of the dorsal borders, and the olfactory lobes as solid without even the orifices distinctly portrayed, though not interpreted, by Stannius and Busch.

In 1864, Mayer (40) published figures of a large number of fishes' brains, as illustrations of his idea that by the relative size and more or less intimate connections of the brain-lobes, fish-like forms could be divided into Pisces Mesencephali (Teleosts), and Pisces Proëncephali (all others including Dipnoans). The eighty-four figures of Teleost brains are mostly original; they usually present only the upper surface and vary in the degree of their accuracy, judging by comparison with preparations of the same species.

The Myzont brain is represented by Müller's figures of *Myxine* and *Bdellostoma*, and by an original and very good figure of *Petromyzon marinus.* His interpretation of the parts differs from both Müller's and my own.

Among Selachian brains are copies of *Galeus* and *Callorhynchus* from Busch, and of *Torpedo* from Savi; the author adding a fœtal *Galeus*, a *Zygœna*, *Squatina*, *Raia*, *Scymnus* and *Chimera;* all are shown from above, *Chimera* alone shows the olfactory lobes; the separation of these from the rest of the brain in the figure is not referred to in the text or regarded by others who have copied the figure.

The brain of *Protopterus* is seen from the side in a copy of Owen's figure and from above in that of Peters.

Mayer copies Busch's figure of the brain of *Lepidosteus semiradiatus*, and by its side gives an original figure of that of *L. osseus* without commenting upon the great difference and form and relative size of parts; both are inaccurate.

Similar unexplained discrepancies appear between the original figures of the brains of *Acipenser sturio* and *Ruthenus*, while that of *Polyodon* agrees neither with them nor with the preparations made by me. There are copies of Müller's figure of the brain of *Polypterus* and of Franque's of that of *Amia.* None of these figures indicate the existence of a lateral ventricle or a foramen of Monro.

The Ganoids together with the Dipnoans are called Hemiepencephali. The Holo-ganoidei include *Acipenser* and *Lepidosteus*, while the Hemi-ganoidei embrace *Amia*, *Polypterus*, *Protopterus* and *Polyodon.*

While sympathizing with Mayer in his attempt to follow out the earlier suggestion of Carus, and make the brain the basis for a subdivision of fishes, I am compelled to say that his determination

of homologies and discrimination of groups, as founded upon the external aspect of preparations (some of which certainly are badly preserved) do not stand the test of a careful structural comparison. A smaller number of figures of sections or dissections of a few typical forms would have more materially aided our comprehension of the brains themselves and of the zoölogical relations of the fish-like Vertebrates.

In 1868 appeared a paper upon the comparative anatomy and development of the brain by Miklucho-Maclay (41).[20]

This author regards the brain of Selachians as typical, and bases his determination of homologies upon the comparison of vertical longitudinal sections of the brains of an embryo shark (*Heptanchus*) and a goat. He concludes that the cerebellum of the shark is a narrow bridge; that the convoluted mass just in front, which is usually regarded as the cerebellum, represents the optic lobes; that the optic lobes are really the thalami (zwischenhirn); and that the hemispheres (vorderhirn) are only partly separated from each other.

Remarking, in passing, that Miklucho-Maclay offers no sufficient reason for the interpretation of the hinder lobes of the brain, I would call attention to the fact that the embryo shark was 130$^{mm.}$ (more than 5 inches) in length, and that, as shown by the figure, the so-called vorderhirn had already nearly filled up.

His diagram of a typical brain (Fig. 1) is not readily or closely comparable with any fish-brain, as it seems to me; and since the author adopts Müller's statement respecting the slight extent of the ventricles in the Myzonts, and neither describes nor figures any part of the brain of a Ganoid or Teleost, we are compelled to regard his interpretation of homologies throughout the branch as open to doubt, on account of the statement that the hemispheres of Ganoids and Teleosts are wholly separated (p. 560); this not being the case in any fish-brain excepting that of *Protopterus*, where the true hemispheres are separate as in Batrachians.

Owen (24, I, figs. 173 and 174) figures from above the brains of a sturgeon copied from Busch, and of *Lepidosteus* apparently original and very imperfect. In both, the masses just in front of the optic lobes are called prosencephala (hemispheres). But, as there figured, the outward aspect of the two brains is so dissimilar

[20] This paper was not obtained by me until February, 1876. The delay in publication of this paper enables me to insert a comment upon it.

and so little indicative of their real structure, that the eminent author seems not to have thought of making any comparison between them. The openings which I shall show to be the "foramina of Monro" are represented in the sturgeon's brain even too distinctly, but there is no reference to them in the text. The cerebellum of the sturgeon is described as a "simple commissural bridge or fold" according to its outward appearance, whereas, by its downward projection into the optic ventricle as a thick keelshaped mass, the cerebellum has a very considerable bulk. The cerebellum of the gar-pike is figured as smooth and described as solid, whereas it is really hollow and presents two longitudinal depressions.

The manual of Gegenbaur (14) contains several figures of fishes' brains. Three represent vertical longitudinal sections of the brains of embryo shark, snake and goat, which are apparently original, although the first resembles that of Maclay. Figures of the brain of *Polypterus* are copied from Müller, and of the brain of a shark from Busch.

Like many continental anatomists, Gegenbaur subdivides the brain into nach-, hinter-, mittel-, zwischen- and vorder-hirn. We have no good English equivalent for *zwischenhirn*, nor do the other names seem to aid the comprehension of the brain type any better than the ancient and convenient latin terms, *cerebellum*, *lobi optici*,[21] *hemispheræ*, *thalami*, etc.

In the present case the nomenclature of the several brains is not homogeneous, even according to the common interpretation that the hemispheres of the frog and other aërial Vertebrates are represented in fishes by the pair of solid lobes in front of the optic lobes, or in sharks by the single median mass from which arise the olfactory crura. The optic lobes of the shark are called zwischenhirn, and those of *Polypterus* mittelhirn; and in the section of the brain of the embryo shark the term mittelhirn is applied to the larger and folded anterior portion of the cerebellum, while the hinder border is named hinterhirn.

Huxley (7, fig. 38), figures the brain of *Lepidosteus osseus* from above and from below. In accordance with the plan of the "Manual" it is not stated whether the figure is original.

Huxley follows the usual nomenclature in making the two pair of lobes in front of the optic lobes respectively hemispheres and

[21] The ponderous phrase *corpora quadrigemina* is rarely employed by comparative anatomists.

olfactory lobes. But he does not refer to the figure in the text, nor does he mention the brain as likely to aid either at present or in the future in the discrimination between the Ganoids and the other fishes.

The figures and descriptions of the brains of Myzonts (Marsipobranchs), Teleosts, and Selachians (Elasmobranchs) are hardly more satisfactory. With none of them is any effort made to ascertain, by a structural comparison, the extent to which they conform to the type of brain commonly recognized among the air-breathing Vertebrates.

This is the more noteworthy because by far the clearest presentation of this type is furnished by the figures and descriptions in the earlier pages of the same work. For these diagrams indeed, as for so many others which bring orderly knowledge out of chaotic detail, the anatomist is greatly indebted to Prof. Huxley.

In this brief historical survey, considering the general desire to ascertain the extent to which Ganoids form a natural group separable from other fish-like forms, one is struck with the absence of both any attempt to characterize the group by means of the brain and of the supposition that such characterization is possible.

Evidently the first step in such characterization should be the identification of parts, if possible, with those which uniformly exist in the brain of all air-breathing Vertebrates, the Batrachians, Reptiles, Birds and Mammalia.

The ganoid brains upon which this paper is based, were all prepared by myself from fish just taken from the water. The difference between these preparations and some previously made from specimens which had been transported for some distance or kept for a time in spirit before the heads were opened, has convinced me that, for the determination of doubtful points of structure, the brain should be hardened in strong alcohol before the fish has been twenty-four hours out of water.

The published figures and descriptions of ganoid brains with which I am acquainted appear to have been made from poorly preserved specimens. Moreover, none of them include all the views (from the side and from below as well as from above) and sections (mesio-longitudinal, and transverse at several points) which are necessary to the presentation of the real structure of a brain. With no other organ is it less safe to trust to the external form and appearance of the several lobes.

How far this is true of the brains under consideration, may be seen by a comparison of the representation (Plate II, fig. 7) of the mesial surface of the brain of *Lepidosteus osseus* with the figures of Huxley (7, fig. 38), or of Owen (24, I, fig. 174), both of which seem to have been made from poorly preserved preparations.[22]

The gar-pike from which was taken the brain here represented, was a female, 1.3 meters (about four and one-half feet) in length. The brain, as is usual with this species, and, so far as I know, with all adult Ganoids, was covered by a layer of connective tissue. This envelope is fatty and yellowish in *Acipenser;* jet black and very abundant in *Polyodon*, the brain of which does not nearly fill the cavity; moderate in amount, and light colored in *Amia* and *Lepidosteus*. In the young of these latter, less than 120$^{mm.}$ long, no envelope exists, the brain quite filling the cerebral cavity. It would be interesting to ascertain at what period commences the increase in the brain case of *Polyodon*.

The brain is represented enlarged two diameters.[23]

The description of the brain of *Lepidosteus* will be more readily followed if we first refer to the general type of brain as found in Batrachians, Reptiles, Birds and Mammals.

The best figures and descriptions of this type of vertebrate brain, are those of Huxley (24, figs. 19 and 20), which, with unimportant changes are reproduced on figure 15.[24]

According to Huxley's description the brain begins as three median vesicles, whose cavities are continuous with the central canal of the spinal cord. The hinder vesicle thickens below to become the *medulla oblongata* (*M*). It opens above to form the fourth *ventricle* (4) and a bridge over the anterior part of this ventricle is the *cerebellum* (*C*). The middle vesicle becomes the *optic lobes* ("corpora quadrigemina" of anthropotomy); its cavity may, as in Batrachians, remain as a wide space, the *optic ventricles*, or be narrowed to a mere "aqueduct of Sylvius" or passageway (*I*) from the fourth ventricle behind to the third ventricle in front.

[22] It is not strange that Europeans have been obliged to content themselves with imperfectly preserved brains of American fishes. But it is little to the credit of our native zoölogists that they have not long ago investigated the structure and development of the forms peculiar to this continent.

[23] Some parts would be more advantageously shown upon a still larger scale. Most fishes' brains can hardly be understood if figured of the natural size.

[24] For the use of these figures I am indebted to Messrs. Estes and Lauriat of Boston.

This third ventricle is the cavity of the anterior vesicle, and its lateral walls become the *thalami* (*Th*). But from each side in front there is produced a hollow bud which enlarges so as to become the *cerebral hemisphere* (*H*). From the front of each hemisphere a second bud is produced, the *olfactory lobe* (*Ol*). The cavity of each hemisphere is a *lateral* (first or second) *ventricle*, (*LV*) and the cavity of the olfactory lobe is the *olfactory ventricle*. The constricted communication between each lateral ventricle and the median third ventricle is known as the "*foramen of Monro*" (*FM*). Median dorsal and ventral outgrowths from the thalamus vesicle become respectively *conarium* ("pineal body," *Co*) and *infundibulum*, the connection of which with the hypophysis (*Hy*) is now regarded as secondary (43, 92).

The thin anterior wall of the anterior vesicle between the hemisphere-buds, remains as the *lamina terminalis* (*Lt*) the "lamina cinerea" of anthropotomy. The *corpus striatum* is a thickening of the outer walls of the hemisphere (*CS*). The various transverse and longitudinal commissures *corpus callosum*, *anterior commissure*, *fornix* and *pons Varolii*, probably do not exist in fishes and need not here be described.

Taking for granted the sequence of principal ganglia, medulla, cerebellum, optic lobes, thalami, hemispheres and olfactory lobes, no difficulty is met in recognizing the three first named in the brain of *Lepidosteus*. But the appearance of these in the section differs considerably from the idea conveyed by the figures of the brain from above and below. The fourth ventricle (IV) extends farther back, and has no bridge across its anterior end as in Huxley's figure. In this species the hinder end is quite sharply pointed. But in a smaller gar from Wisconsin, not yet identified, the ventricle is shorter, its borders are raised and everted, and the hinder extremity less sharp. The borders also approach each other quite nearly, just behind the cerebellum, which, with a poorly preserved preparation, might lead an artist, not an anatomist, to regard them as normally continuous.[25]

If figure 7 be held with the olfactory lobe upward, then the section of the entire cerebellum may be compared to a letter S, the lower curve larger and its substance thicker than the upper.

The lower, or, if the figure be replaced in the horizontal posi-

[25] Huxley's figure purports to be of the brain of *L. semiradiatus*, Ag. Günther regards this as a synonym of *L. osseus*.

tion, posterior curve, represents the cerebellum proper. The anterior curve corresponds to the "valve of Vieussens" of anthropotomy, and to the "fornix of Gottsche" referred to by Huxley in his description of the brain of Teleosts (7, 142).

This part is about one-half the thickness of the cerebellum itself, and it becomes an exceedingly thin lamina where it joins the overhanging posterior border of the optic lobes. The cerebellar ventricle is quite extensive, its vertical diameter being more than twice and its longitudinal diameter more than thrice, the thickness of the lamina by which it is surrounded.

About midway between the posterior rounded border of the cerebellum and the free thin edge of its anteverted portion upon the ventral aspect, is a low ridge. Laterally this is in apposition with a corresponding everted edge of the medulla.

The dorsal surface of the cerebellum presents on each side a rather deep furrow separating the median rounded portion from the peduncle on each side.

The "aqueduct of Sylvius" (*AS*) is a rather contracted passage from the fourth ventricle to the ventricle of the optic lobes.

The dorsal aspect of the optic lobes inclines downward and forward at about the same angle as that at which the cerebellum inclines backward. The thickness of the cut surface is about the same as that of the "fornix of Gottsche," but the anterior margin is slightly thickened and rounded. At this point the expanded optic ventricle (*OV*) opens forward by a contracted aperture surrounded by a flaring lip. The conarium or pineal body (*C*) lies just in front of this aperture.

So far there seems no reasonable cause for doubting the correctness of the commonly accepted nomenclature. But the anterior half of the brain of *Lepidosteus* presents serious difficulties in the way of strict comparison with the brains of the higher Vertebrates.[26]

The form and connections of the parts marked 2, 3, 4, cannot be well indicated without more figures, especially cross-sections. These I hope to present upon another occasion.

The third ventricle (III) opens downward into a cavity with walls thicker before and behind but thin upon the sides. It ex-

[26] To say nothing here of the brains of the Myzonts, Selachians and Teleosts, with which considerable rectification is required, as will be shown hereafter.

tends under nearly the whole width of the brain and opens downward by a median slit into what seems to be a plexus of vessels.

The hollow lateral lobes are what Owen calls "hypoaria" and Huxley, with most authors, "lobi inferiores." The lower solid vascular mass corresponds to what is commonly called the pituitary body or hypophysis. It is easily detached, and is not, so far as I am aware, represented in any figure of a Ganoid brain.

Pending an examination of the brain of *Lophius*, the hypophysis of which lies far in front of the brain connected with its usual attachment by a very long infundibulum, I am inclined to regard the lobi inferiores as lateral expansions[27] of what is called in anthropotomy the *tuber cinereum.*

There remain to be described the two pair of masses which, in *Lepidosteus* as in most Teleosts, are placed just in front of the optic lobes. They are at the present time usually regarded as representing respectively the hemispheres and olfactory lobes.

According to the type of brain as described by Huxley and generally accepted, the hemispheres should be lateral masses separate from each other and each containing a cavity, the lateral ventricle, communicating with the median or third ventricle through a foramen of Monro.

Yet, so far as I am aware, no such condition of things has been figured or described with respect to the brain of any fish-like form excepting Protopterus and Lepidosiren.[28] (See Appendix.)

In the brain of the adult *Lepidosteus*, the lateral mass marked *PTh* is a solid lamina with its upper or dorsal border everted, as seen in the transverse section (Fig. 11). The mesial surface of its rounded dorsal aspect presents two furrows. It is joined with its fellow of the opposite side by a large commissure (*B*)[29] and by a thinner lamina reaching back to the optic chiasma.

[27] Dr. Cleland (38, 201) regards the hypoaria of osseous fishes as the thalami, and states that "in various fishes, the optic nerves arise from them as well as from the optic lobes." Dr. Cleland's learning and accuracy are such that I would not reject his view upon less grounds than those here presented. But I have not observed the origin of the optic nerves from the hypoaria in any fish.

[28] Tiedemann frankly admits (35, 264), that "we find no trace of lateral ventricles in the osseous fishes;" he regarding the so-called hemispheres as the corpora striata (p. 230). Contrast this with the loose statement of Vulpian (31, 821), "on trouve parfois des rudiments de ventricules lateraux dans les lobes cérébraux" of osseous fishes.

The so-called ventricles of Selachians will be shown hereafter to be remnants of the third ventricle; not rudiments of the first and second.

[29] This is apparently what Gottsche called in osseous fishes, "commissura interlobularis."

Just in front of each of these lobes is a rounded orifice opening obliquely outward and forward into the base of the anterior or olfactory lobes.

This orifice is wholly invisible from above or below or from the outer side, and, although figured by Stannius in the sturgeon, seems to have attracted no attention from those who have studied Ganoid brains.

It leads into a cavity which extends the whole length of the so-called olfactory lobe, and is about $1^{mm.}$ in diameter.

As this is the only lateral opening from the median ventricle there seems to be no escape from the conclusion that it is the "foramen of Monro," and that the cavity into which it leads is, wholly or in part, the lateral ventricle.

Where then are the hemispheres?

The mesial border of the foramen of Monro is slightly raised, so as to be distinguishable upon close inspection from the olfactory lobe. Still it is very small, and upon a poorly preserved specimen, or under a brief examination it might escape notice altogether.

But if the corresponding parts of other Ganoid brains be carefully examined, they will be seen to present the same foramen, while in all of them the anterior lip is decidedly broader, presenting the appearance of a separate lobe. See figures 8, 9, 10.

Shall we conclude that the hemisphere and olfactory lobe are undifferentiated, or regard the lip already described as a rudimentary hemisphere. This latter is the conclusion to which I am inclined.

It involves, as a corollary, the interpretation of the lateral masses between the optic lobes and those just described, as representing the whole or some part of the *thalami*, or *lobi ventriculi tertii*.

In *Lepidosteus* one would be inclined to regard the lateral masses as the whole thalamus. But in *Amia* the distance between the front of the optic lobes and the hinder surface of these masses equals that of the masses themselves. In *Polypterus* likewise, as figured by Müller, it is considerable. In *Chimera* what seems to be a corresponding region is very much elongated. In most Selachian brains it is quite extensive.

For the sake of distinction therefore, we may call the anterior lateral masses *prothalami*, and the portion connecting them with

the brain behind the *crura thalami*. These latter seem to correspond to the thalami of the higher Vertebrates; the third ventricle lies between them, the conarium above and the hypophysis below.

Aside from the adverse opinions of all authors (which, however, are of less importance in view of the imperfection of the material at their disposal) the only objection to this view is, that it makes the hemispheres so much smaller than either the thalami or the olfactory lobes.

It is to be remembered, however, that mere size is of no value for the determination of homologies. The cerebellum is recognized as such in the lamprey and the salamander because it is a bridge over the fourth ventricle, although it is so much smaller than the corresponding organ of the bird or mammal.

The hemispheres are hardly larger than the optic lobes in some Batrachians, while in man they overshadow all the other parts.

Now the hemispheres are, by development, mere buds from the thalami, yet, as may happen with human families, the offspring are larger than the parents. In like manner, in the Ganoid brain, the hemispheres themselves are surpassed in size by their buds, the olfactory lobes.

But while regarding the view here advanced as based upon sound morphological grounds, the large size and convoluted surface of the thalami suggests the idea that they may in some way *functionally* represent the hemispheres.

For the determination of this the brain should be examined microscopically and the fibres from the medulla should be traced forward into the several lobes as has been done with the frog by Wyman and Stieda. They should also be experimented upon by injury, ablation and galvanic stimulation.

To complete the evidence we should find, at least in young specimens, something like a *lamina terminalis*, connecting the rudimentary hemispheres just in front of the foramina of Monro. No such has been found by me in *Amia* or *Lepidosteus*, but the sturgeon and *Polyodon* present a transverse curtain with foldings upon the deep surface resembling those of the curtain over the fourth ventricle of Batrachians and lamprey-eels. Though not, apparently, of nervous tissue, it may nevertheless, represent the lamina terminalis. For there is reason to believe that, in the course of development, many parts of the roof of the primary vesicles may become merely connective and vascular tissue.

In a young *Lepidosteus* 151$^{mm.}$ long, the dorsal borders of the prothalami are not everted as in the adult. For reasons which will be understood when the brains of Selachians and Myzonts are described, I am inclined to think that at an earlier period of development the dorsal borders were united.

Detailed descriptions of the brains of the other Ganoids are deferred until figures can be presented. That of *Amia* closely resembles that of *Lepidosteus*, especially in the cerebellum. The infundibulum is more folded. The crura thalami are considerably longer.

The brain of *Acipenser*[30] and *Polyodon* are very similar in both structure and general appearance. In both the cerebellum is apparently a narrow bridge, but, as seen in the figure of Stannius, it really extends far forward into the optic ventricle, as an exaggerated fornix of Gottsche. The walls of the optic lobes are thicker in *Polyodon* than in *Acipenser*. The brain of *Scaphyrhynchus* was not obtained for examination. There is no reason for supposing it to differ essentially from that of *Acipenser*.

Müller's figures and descriptions of the brain of *Polypterus* do not allude to the communication between the median ventricle and the olfactory ventricles, but the figures are quite insufficient, and pending its examination with reference to this point, we may infer that it agrees with *Lepidosteus* in this respect as in the eversion of the thalami.

The brain of *Calamoichthys* is not known to me. We may even more naturally infer its agreement with that of *Polypterus*.

Provisionally, at least, the seven genera, *Amia* and *Lepidosteus*, *Polypterus* and *Calamoichthys*, *Acipenser*, *Scaphyrhynchus* and *Polyodon*, may be associated as having *rudimentary hemispheres in the form of slightly raised borders of the foramina of Monro and much smaller than the olfactory lobes; large prothalami connected below by a commissure but having their dorsal borders free and more or less everted; an optic chiasma; a rythmically contractile and multivalvular bulbus arteriosus.*

Fig. 12 shows a mesial section of what seems to me to be a typical Ganoid brain with cross sections at characteristic points.

Let us now see whether the above definition includes any other Vertebrates.

[30] Three species of this genus were examined, *rubicundus*, *oxyrhynchus*, and one as yet undetermined.

Amphioxus appears to have only a medulla with a fourth ventricle. The part in front of the ventricle may be regarded as an undifferentiated representative of the brain of the higher Vertebrates (Langerhans (44, 297) says he finds a small olfactory lobe).

In *Myxine* and *Bdellostoma*, Joh. Müller (37), found no ventricle in front of the fourth, and no cerebellum. In a somewhat injured preparation of the brain of *Myxine*, I find what seems to be a thin and rudimentary cerebellum; and a median ventricle which extends forward to the base of the anterior pair of lobes, which Müller and all other authors regard as the olfactory lobes. On each side at this point is a slit-like orifice leading into the cavity of the olfactory lobe. These can be no other than the foramina of Monro and lateral ventricles. The hemispheres are hardly distinguishable from the olfactory lobes. The larger pair of lobes just behind, since they form the walls of a median ventricle must be regarded as the undifferentiated prothalami and thalami. They differ from those of Ganoids in being connected above as well as below. But behind them are the conarium and the orifice of the optic ventricle just as in the brain of *Lepidosteus*. In *Petromyzon* Müller found (37) the third ventricle only. In several well preserved preparations of the brain of the large sea-lamprey (*P. marinus*, var. *Americanus*), I find at the anterior extremity of this median cavity, as in *Myxine*, a foramen of Monro leading into the olfactory or lateral ventricle. The thalami are closed above as in *Myxine*. The distinct lobes which project just behind the olfactory lobes are probably hemispheres. (See Appendix.)

Müller describes the optic nerves of the Myzonts as not crossing at all. Upon this ground, as by the non-separation of the thalami above and the lack of several rows of valves in the bulbus arteriosus, they differ from the Ganoids. In figure 13 (*M*) is represented a cross section of the brain of *Petromyzon* through the thalami. (See Appendix.)

The Selachians (here restricting the term to the sharks and skates) have a brain which is really only a complex modification of the Lamprey's. In an embryo shark (*Mustelus canis*) 37^{mm} (about 1½ inches) in length, that part which gives rise to the olfactory crura and which has been variously interpreted as hemispheres alone, hemispheres and thalami, and thickened lamina terminalis, is a large vesicle with thin walls and a single cavity. This communicates behind with the optic ventricle and on each

side in front with the cavity of a little bud which is in contact with the nasal sack. The vesicle is evidently the expanded prothalamus closed above as in the Myzonts. In the adult Selachians (as I hope to show by a series of figures at a future time) we must suppose the original median cavity to have gradually filled up so as to leave only two slender passages, near the lower wall, which start from opposite the optic foramen behind, and diverge to enter the olfactory ventricles in front. The degree of differentiation of the crura thalami, and the hemispheres, will be more fully described hereafter. In some forms the hemispheres are distinctly constricted from the sides of the nearly solid prothalamus. Although, therefore, the optic chiasma and multivalvular and contractile bulbus and some other characters are common to Ganoids and Selachians, the prothalamus is open in the former and closed in the latter. In these and some other respects the contrast between the two groups is noteworthy. In figure 13, *ES* represents a cross section of the prothalamus of an embryo shark and *AS* that of an adult.

The Holocephali (*Chimera* and *Callorhynchus*) are commonly arranged with or near the Selachians. They have many features in common and the intromittent organs upon the ventral fins are usually regarded as very important. Being a purely sexual apparatus we may question whether their taxonomic value is equal to that of the brain. Not having had the opportunity of examining a brain[31] I can only judge from the figure by Busch, copied by

[31]Just as this goes to press I am enabled, through the kindness of Mr. Alex. Agassiz, to expose and examine the brain of a well-preserved male *Chimera* in the Museum of Comparative Zoology. The cerebellum is very large and covers the optic lobes, but is not folded transversely as in most, if not all, adult sharks and skates. The crura thalami are very long and thin and united ventrally by a delicate membrane apparently only pia mater. Anteriorly each crus expands into a prothalamus, the dorsal border of which is thin and slightly everted. This prothalamus, however, instead of forming the principal anterior mass as in Ganoids, is overlapped outside by a large and elongated hemisphere about 8mm. in height and 15mm. in length. On the hinder third of the mesial surface is a large rounded foramen of Monro, 4mm. in diameter. The lateral ventricle extends forward into the olfactory lobe. Into the foramen, and occupying its entire area, projects a thickening of the outer wall of the hemisphere which may represent a primordial corpus striatum. Just in front of the foramen the ventral borders of the hemispheres are connected by a transverse commissure. I greatly regret not having been able to examine this brain before presenting this paper. It seems to furnish an actual form intermediate between the apparently distinct types represented by the brains of Selachians, Ganoids and Dipnoans. If I correctly interpret the appearance of a partial subdivision of the elongated mass behind the olfactory lobe the Chimera's brain presents a more equal proportion of hemisphere and prothalamus than exists in Ganoids or Teleosts, where the former seems to be reduced to a rudiment hardly recognizable as such.

Owen (24, fig. 179). The cerebellum appears like that of the sharks and skates. But the elongated crura thalami, and what seem to be somewhat expanded prothalami, and the rudimentary hemispheres, indicate a close similarity with the Ganoid type. The brain should be carefully reëxamined, and that of a very young embryo would be especially valuable.

The figure of the brain of *Protopterus* (Owen, 25 and 24) might be taken for that of *Menopoma* or *Menobranchus*. It has no apparent resemblance to either the Ganoid or the Selachian type. There are also true nostrils, and, according to Huxley (7, 147), a small pulmonary auricle. These characters united with those of the brain seem to offer strong grounds against the association of the Dipnoi with the Ganoids, excepting as a very generalized type combining Ganoid and Batrachian features. The brain of *Ceratodus* has not been described.[32]

Of fish-like forms there remain the Teleostei. They may at once be distinguished from all others by the non-rythmically contractile bulbus provided with a single row of valves and by the decussation of the optic nerves without a chiasma.[33]

A sufficient number of Teleost brains has not yet been carefully examined to enable us to generalize with safety. But so far as they are known we may characterize them as having solid lateral masses (prothalami), their dorsal borders separate and sometimes everted, and with the olfactory lobes sometimes in contact with the prothalami, sometimes in contact with the olfactory sacks and connected with the prothalami by more or less elongated crura.

Since this paper was presented I have found small foramina of Monro and ventricles in *Perca flavescens*, *Anguilla Bostoniensis* and *Scomber vernalis*. They, however, are much smaller

[32] In "Nature" for Jan. 6th, 1876, it is stated that Prof. Huxley described, for the first time, the brain of *Ceratodus* at the meeting of the Zoological Society, Jan. 4th; that he showed how closely it resembled that of *Lepidosiren*, and that in some points it resembled the Selachian rather than the Ganoid type. He laid especial stress upon the affinities of the animal with *Chimera*.

Zoölogists will look with great interest for this paper on account of the description and figures of the brain of a form which has aroused so much discussion, and also for the morphological and taxonomic considerations which can hardly fail to throw great light upon the relations of the fish-like Vertebrates.

[33] Gottsche (30, 476, and fig. xxxiii), refers to a remarkable variation of the optic nerves described by Weber (Meckel's Archiv, 1872, p. 317). In an example of *Clupea harengus* the nerve of the left eye was pierced by that of the right. The *structure* of the chiasma of Ganoids and Selachians should be carefully examined to ascertain how completely the fibers cross, or intermingle, or connect the eyes and lobes of the two sides together.

than in Ganoids, and I give a provisional figure (Fig. 14) mainly for the purpose of calling attention to the point where they are to be looked for. Probably they are proportionally larger in embryo brains. They may become wholly obliterated in some adults, especially those with olfactory crura. They should be looked for in large species, as *Esox*, *Xiphias*, *Hippoglossus*, etc., where the olfactory lobes are sessile.[34]

The following table exhibits the above mentioned characters in a more condensed form. But it must not be inferred that the order of names indicates my belief respecting either their rank, their affinities, or geological succession. In the first place no linear arrangement can do this. In the second, while the Teleosts seem to most perfectly and abundantly embody the *fish idea* and their geological relations and the structure of some parts would lead us to place them highest in the fish series, yet the non-mingling of the optic nerves and the very embryonic condition of the kidneys as compared with those of Selachians,[35] seem to place them next the Myzonts.

The air-breathing Vertebrates are added in order to complete the series.

Provisional Arrangement of Vertebrates according to Cerebral and Cardiac Characters.

Leptocardii. (*Amphioxus*). Brain not differentiated from medulla. Heart a contractile tube.

Myzonts. (Marsipobranchii). Optic nerves do not cross (Müller). Single median nostril. Hemispheres smaller than olfactory lobes. Thalamus and prothalamus not distinctly separated. Thalamus closed forward and dorsad. Cerebellum a narrow and thin lamina; perhaps wanting in Myxinoids. (See Appendix.)

Selachians. (Elasmobranchii.) Optic chiasma. Rhythmically contractile bulbus arteriosus, with several rows of valves. Olfactory lobes pedunculated. Hemispheres smaller than olfactory lobes. Prothalami and thalami distinct; the latter as crura. In

[34] The brains must be well preserved.

[35] As recently studied by Balfour (39, 30).

embryo the prothalamus a thin-walled vescicle, with a single cavity which, in adult, is reduced to two canals diverging forward. Prothalamus remains closed forward and dorsad. Nostrils in pairs, but do not enter mouth. Cerebellum folded transversely.

HOLOCEPHALI. Brain combines characters of Selachians, Ganoids and Batfachians. Crura thalami much elongated. True hemispheres, larger than prothalami or olfactory lobes. Foramen of Monro very large. (The last two sentences have been added since this paper was read. See notes 31 and 36.)

GANOIDS. Optic chiasma. Rhythmically contractile bulbus arteriosus with several rows of valves. Hemispheres rudimentary. Olfactory lobes sessile. Prothalami separate forward and dorsad, and more or less everted. Cerebellum with no transverse folds. Foramina of Monro large.

TELEOSTS. Optic nerves cross but form no chiasma. Bulbus arteriosus not rhythmically contractile and has a single series of valves. Olfactory lobes sessile or pedunculated. So-called hemispheres are probably prothalami; more or less everted as in Ganoids, and separate forward and dorsad. True hemispheres rudimentary or absent. Foramina of Monro and lateral ventricles small or, perhaps in some, obliterated. (Last sentence added since this paper was read.)

DIPNOANS. Hemispheres larger than olfactory lobes. Heart trilocular. True nostrils. Optic chiasma. (Should probably be arranged with or near Batrachians in the Series of air-breathing Vertebrates).

BATRACHIANS. Hemispheres larger than olfactory lobes. Heart trilocular. Optic chiasma. No corpora striata or commissures. Walls of brain thin and ventricles large. True nostrils.

REPTILES. True hemispheres. True nostrils. Corpora striata and anterior commissure. Heart trilocular or quadrilocular. Right and left aortic arches persistent.

BIRDS. Same brain characters as in Reptiles. Heart quadri-

locular. Right aortic arch persistent. (Birds seem to be an aberrant group of Sauropsida.)

MAMMALS. Corpora striata. Anterior commissure. Corpus callosum. Fornix. Pons varolii. Heart quadrilocular. Left aortic arch persistent.

By characters of the brain alone the Ganoids are readily separable from all other vertebrates. From the Teleosts they differ in respect to the optic chiasma; also, so far as now known, on account of the greater size of the lateral ventricles and foramina of Monro.[36] But differences of size alone are not reliable; and our knowledge of the structure of the Teleost brain must be much extended before final generalizations can be made. Meantime it is interesting to note that some cerebral characters seem to associate the Ganoids with the Teleosts, while others, with cardiac characters, link them with the Selachians. The Teleosts are apparently an aberrant group, like the Birds.

Minor modifications of the brain, together with those of the tail and air-bladder, will probably furnish the basis for subdivision of the Ganoids. The brains of *Amia* and *Lepidosteus* are very nearly alike, and both seem to agree in all essential respects with that of *Polypterus*, and, by inference, *Calamoichthys*. The brains of the Sturgeons resemble one another more closely than they do those of the other genera, but all agree in the rudimentary hemisphere, the enlarged prothalami, and the position of the foramen of Monro.

Reserving for the present any discussion as to the separation of Dipnoans from Batrachians, and of Birds from the other Sauropsida, the groups seem to readily fall into five categories. The first and lowest includes *Amphioxus* alone. The second the Myzonts and Selachians, whose brains are differentiated, but have not yet assumed the distinctive features of either the true aquatic or the aërial Vertebrates. They have the form and habit of fishes, but their brains are more readily comparable with those of Batrachians. For the hemispheres are distinct, though small, and the thalamus remains closed, instead of being separated forward and

[36] At the time this paper was presented I had not been able to find these openings in any Teleostean brain, and therefore supposed that their existence in the Ganoids formed a sharp distinction between the two groups.

dorsad, as in the Teleosts, the Ganoids and Holocephali. The Holocephali cannot yet be fully characterized. The brain presents a very generalized condition. These and the other characters may be more distinctly presented in tabular form.

Series V. Hemispheres well developed; larger than olfactory lobes. Pulmonary auricle. True nostrils.

Mammals.
Birds.
Reptiles.
Batrachians.
Dipnoans.

Series IV. Hemispheres rudimentary or absent; smaller than olfactory lobes. Prothalamus open forward and dorsad. Dorsal borders of prothalami more or less everted. Heart bilocular. Nostrils do not enter mouth.

Teleosts.
Ganoids.

Series III. Holocephali. Brain presents a condition intermediate between Series II, IV and V.

Series II. Hemispheres distinct but smaller than olfactory lobes. Thalamus not open forward or dorsad. Heart bilocular. Nostrils do not enter mouth.

Selachians.
Myzonts.

Series I. Brain not differentiated from medulla. Heart tubular.

Amphioxus.

To such an arrangement of vertebrates as the above the palæontologist would naturally object upon the ground that it includes no osteological characters by which fossil forms may be collocated with the living.

To this I plead guilty, but urge in extenuation the following:

1. The *argumentum ad hominem*. For the classifications now in vogue make little or no reference, or that of the most unsystematic kind, to the brain; and osteological characters alone would not enable us to define embryos, Myzonts, or *Amphioxus* at all.

2. The above does not pretend to be a complete or final arrangement. It is an effort to show how far cerebral and cardiac characters concur with each other and with the results of a previous consideration of all systems of organs. Such an effort could hardly be successful before the brains of fishes were structurally homologized with those of the air breathing Vertebrates.

3. I should be willing to have it shown that I had made some

mistakes as to both fact and interpretation, for the sake of the advantages which I am confident will attend the careful and systematic reconsideration of our present methods of classification. These last are almost purely empirical. They have, as in the case of the Ganoids, led to the most diametrically opposite conclusions. Would it not be worth while to enquire whether, from both analogy and experience, cerebral and cardiac characters are not more trustworthy for the discrimination of larger groups, and whether characters drawn from the skeleton, teeth, digestive and reproductive systems are not likely to serve us better if restricted to the determination of orders, families and genera.

When the limits of classes and sub-classes have been once ascertained by the study of the heart and the brain, most of the fossil forms may, by the correlations of their hard parts be assigned to places in them. At present, on account of the greater availability of hard parts for preparation and preservation, we practically depend upon them almost entirely, or tacitly assume that they are of greater taxonomic value than the soft parts, and that the latter are, therefore, readily correlated with the former.

SUMMARY. 1. The smallest *Lepidosteus* here described ($18^{mm.}$ long), has a primordial median fin extending over the hinder third of the body above, and its hinder half below, interrupted at the vent.

2. The locations of the dorsal, the anal and the infra-caudal fins are marked by coloration and thickening of the primordial fin.

3. A fourth or supra-caudal fin is also indicated, though less decidedly. This fin is not functionally developed.

4. The tail of this smallest *Lepidosteus* is nearly protocercal, the end of the body inclining slightly downward.

5. The end of the body proper is gradually forced upward by an increase of the infra-caudal lobe, and becomes the "filament" already known in the young gar-pike.

6. The movements of this filament are extensive, and vibratory, and wholly voluntary.

7. The filament exists, though evidently in process of removal, in a young *Lepidosteus osseus* $300^{mm.}$ long.

8. The infra-caudal lobe becomes the functional tail of the adult.

9. The vertebral column is then continued obliquely upward and backward as a tapering cartilaginous rod which terminates at a point corresponding with the previous separation of the filament

from the infra-caudal lobe. This point coincides with the hindermost of the dorsal fulcra.

10. This rod comprises the notochord, the spinal cord and two lateral cartilaginous pieces.

11. The tail of the adult *Amia* presents a similar structure, excepting that the rod is shorter and there are no fulcra.

12. It seems probable that the tail of *Amia* passes through stages like those of *Lepidosteus*, but the smallest specimen here described ($70^{mm.}$ long) shows no sign of the filament.

13. The two earlier stages of the tail of *Lepidosteus* may be compared with the protocercal (or diphycercal) and the ordinary heterocercal tails of other living and fossil forms. The *masked* heterocercal tail of *Amia* and *Lepidosteus* probably existed in *Megalurus* and some other mesozoic forms, but is not known among the palæozoic fishes. It likewise exists in the embryo of certain Teleosts, as *Gasterosteus* and the Siluroids.

14. The pectoral fins of *Lepidosteus* attain considerable size before the appearance of the ventrals.

15. The latter are not lobed, but the former consist of a fleshy lobe and a thin fringe or border.

16. In the smallest *Lepidosteus* the branchiostegal membranes are separate farther forward than in the adult. The point of their junction in the young becomes a transverse fold, which may correspond with the hinder border of the jugular plate of *Amia*.

17. The "foramina of Monro" and lateral ventricles have been found by me in the following Ganoids:—*Amia*, *Lepidosteus*, *Acipenser* and *Polyodon;* and in the following Teleosts:—*Perca*, *Scomber*, *Anguilla;* in *Chimera;*[37] in the following Selachians:—*Mustelus*, *Carcharias;* and in the Myzont genera *Myxine* and *Petromyzon*. There is good reason to believe that *Scaphyrhynchus*, *Polypterus* and *Calamoichthys* have the same parts; and that they exist in other Teleosts, but less easily seen than in Ganoids, or perhaps wholly obliterated in the adults of some species. In both Ganoids and Teleosts the foramen of Monro seems to open into the base of the anterior or olfactory lobe on each side.

18. Aside, therefore, from the difference in general aspect and in size of the foramina and ventricles, the Ganoid and Teleost brains, as heretofore, are most readily distinguished by the *chiasma* which exists in the former group.

[37] As stated on previous pages the foramina were found in *Chimera* and the Teleosts after this paper was presented.

19. We may regard, provisionally, the seven genera, *Amia*, *Lepidosteus*, *Polypterus*, *Calamoichthys*, *Acipenser*, *Scaphyrhynchus* and *Polyodon* (together with such fossil forms as are obviously allied to them) as constituting a natural group (class or sub-class) characterized by an *optic chiasma; a rhythmically contractile bulbus arteriosus with several rows of valves; large prothalami separate above but united below; rudimentary hemispheres;* and the *foramina of Monro opening apparently into the base of the sessile olfactory lobes.*

20. It seems probable that by features of the brain and heart alone, all of the primary subdivisions of Vertebrates may be accurately characterized.

21. The Dipnoans, hitherto regarded as fishes and usually arranged with or near the Ganoids, agree with the Batrachians in cerebral and cardiac and other characters. This group seems to furnish a case for testing the relative taxonomic value of characters derived from the brain and heart on the one hand and from the skeleton, limbs and digestive organs on the other. In like manner the brain of Holocephali would indicate that they belon nearer the Ganoids than the Selachians, perhaps as a transition between the two.

22. While the facts and considerations presented in this paper cause me to doubt the correctness of all classifications of fish-like Vertebrates hitherto proposed, they do not seem to justify the framing of another system. Nor is it probable that any phyllogenetic arrangement can be proposed which shall either advance science or reflect credit upon the propounder, until our knowledge of the embryology, of the brains and of fossil forms is much more extensive than at present.[38]

APPENDIX.—Just as this goes to press I have been able to consult the admirable paper of Paul Langerhans, "Untersuchungen über *Petromyzon Planeri*," pp. 114, 16mo, 10 Tafeln. Freiburg, 1873. This author figures and describes (p. 83) the lateral and olfactory ventricles of *Petromyzon*. He also states (p. 95) that an *optic chiasma does exist*. These statements must be considered in connection with paragraphs upon pages 178, 182, 185 of this paper.

[38] As this paper is passing through the press, I have seen in the "Zoölogical Record" for 1872, page 86, an abstract of a memoir by Panceri and De Sanctis "Sopra alcuni organi della *Cephaloptera*, Napoli," 1869, 4to. The authors recognize four types of brain besides that in *Amphioxus*; namely, in Cyclostomata; in Teleosts; in four Selachian genera, *Dicerobatis*, *Zygæna*, *Myliobatis*, *Trygon*; and in all other Selachians and Ganoids.

No mention is made of the lateral ventricles or foramina of Monro, and, so far as indicated by the abstract, the conclusions are very different from those here presented.

WORKS AND PAPERS REFERRED TO.

1. AGASSIZ, LOUIS: Lake Superior; its physical character, vegetation, and animals. pp. 428; 8 plates. Boston, 1850.

2. AGASSIZ, Ls: Young gar-pikes from Lake Ontario. (Proceedings Boston soc. nat. hist., 1856; vi, 48.)

3. AGASSIZ, Ls: Observations sur les metamorphoses des poissons. (Ann. des sci. nat. 1865. III, 55—58.)

4. DUMÉRIL, A.: Histoire nat. des poissons. (Ganoides, Dipnoans, Lophobranches) 8vo, pp. 623. Planches.

5. AGASSIZ, LOUIS: Recherches sur les poissons fossiles. 1833-1845. 4 volumes, quarto.

6. HUXLEY, T. H.: Preliminary essay upon the systematic arrangement of the fishes of the Devonian epoch. (Memoirs of the geological survey of the United Kingdom. Decade x, 1861.)

7. HUXLEY, T. H.: Manual of the comparative anatomy of vertebrated animals. N. Y., 1872.

8. HUMPHREY, G. M.: On the homological relations to one another of the mesial and lateral fins of osseous fishes. (Journal of anatomy and physiology, Nov., 1870. 59-66.)

9. AGASSIZ, L.: Notice of a collection of fishes from the southern bend of the Tennessee River. (Am. journ. of science, new series, No. 21. 353-365.)

10. FRANQUE, HENRICUS: Amiæ calvæ anatomiam descripsit tabulaque illustravit, folio, pp. 12; 1 plate. Berlin, 1847.

11. WYMAN, JEFFRIES: Observations on the development of *Raia batis*. (Memoirs of American academy of arts and sciences, Jan. 27, 1874.) 44 pages quarto, 1 plate.

12. GILL, THEODORE: Arrangement of the families of Fishes. (Smithsonian miscellaneous collections. [274], 1872.)

13. GOODSIR, JOHN: Anatomical memoirs. 8vo, 2 vols. pp. 993, many plates and figures. Edinburg, 1868.

14. GEGENBAUR: Grundriss der vergleichende Anatomie. 8vo, pp. 406, 320 figures. Leipzig, 1874.

15. HUXLEY, T. H.: Observations on the development of the tail in Teleostean fishes. (Quart. journal of microscopical science, vii, 33-44; plate III. 1859.)

16. LÜTKEN, C.: On the limits and classification of the Ganoids. (Translation.) (Annals and magazine of natural history, May, 1871. 329-339.)

17. COPE, E. D.: Observations on the systematic relations of fishes. (Proceedings Am. asso. for adv. of science, 1871, 317-343.) [Preliminary publication, slightly different, in American naturalist, 1871, 579-593.]

18. MÜLLER, JOHANNES: Ueber den Bau und die Grenzen der Ganoiden und über das natürliche System der Fische. (Abhandling der Königlichen Akademie der Wissenschaften zu Berlin, 1844. 4to, 117-216,) 16 plates.

19. GÜNTHER, ALBERT: Description of *Ceratodus*, a genus of Ganoid fishes recently discovered in the rivers of Queensland; Australia. (Philosphical transactions, 1871, 511-571. 42 plates.)

20. AGASSIZ, LOUIS: A journey in Brazil, 8vo, pp. 540. Illustrated. 1868.

21. AGASSIZ, L.: An essay on classification. 8vo, pp. 381. London, 1859.

22. AGASSIZ, LOUIS: The classification of the Siluroid fishes. (Proc. Boston soc. nat. hist., Dec. 18, 1868. p. 354.)

23. WYMAN, JEFFRIES: Anatomy of the nervous system of *Rana pipiens*. (Smithsonian contributions to knowledge, v, art. 4, 1855, quarto, pp. 51. 2 plates.

24. OWEN, RICHARD: Comparative anatomy and physiology of vertebrates, 3 volumes, 8vo, pp. 2155. 1471 figures. London, 1861-1868.

25. OWEN, R.: Description of *Lepidosiren (Protopterus) annectens*. (Linnæan transactions, xviii, 327-361), 5 plates.

26. NEWBERRY, J. S.: Description of fossil fishes of Ohio. pp. 110, 17 plates. (Geological survey of Ohio. Vol. 1, 1873.)

27. POEY, F.: Observations on different points in the natural history of Cuba. (Annals of the lyceum of nat. hist. N. Y., 1858. vi, 136.)

27. WILDER, B. G.: The lateral position of the vent in *Amphioxus* and in certain batrachian larvæ. (Proc. Am. asso. for adv. of science, 1873.) pp. 25, 10 figures.

28. MÜLLER, J.: Bericht über die Fortschritte der vergleichenden Anatomie der Wirbelthiere in Jahre, 1842. (Archiv für Anat. 1843; ccxxxviii–cclxi.)

29. BUSCH, W.: De Selachiorum et ganoideorum encephalo. 4to; 1848.

30. GOTTSCHE, C. M.: Vergl. Anat. des Gehirns der Gratenfische. (Arch. für Anat, 1835; 244–294, 433–486; Taf. iv und vi.)

31. VULPIAN, A.: Leçons sur la physiologie générale et comparative du systeme nerveux. 1861; 8vo; pp. 20.

32. STANNIUS, H.: Ueber den Bau des Gehirns des Störs. (Archiv für Anatomie, 1843, 36–44; taf. III, H.)

33. VALENTIN: Ueber das centrale Nervensystem und die Nebenhorzen der *Chimæra monstrosa*. (Arch. für Anatomie, 1843, 25–45. Taf. II.)

34. HOLLARD, H.: Recherches sur la structure de l'encéphale des poissons et sur la signification homologique de ses différentes parties. (Robin's journal de l'anatomie, 1866. 286–335, pl. v–viii.)

35. TIEDEMANN, F.: The anatomy of the fœtal brain; with a comparative exposition of its structure in animals. English translation. pp. 321; 14 plates. Edinburgh, 1826.

36. MÜLLER, JOHANNES: Ueber den eigenthümlichen Bau des Gehörorganes bei den Cyclostomen, mit Bemerkungen über die ungleiche Ausbildung der Sinnesorjane bei den Myxinoiden. pp. 34, Taf. 1–3. (Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, 1837.)

37. MÜLLER, JOHANNES: Vergleichende Neurologie der Myxinoiden. pp. 8. (Abh. der Königl. Akad. zu Berlin, 1838.)

38. CLELAND, JOHN: Animal physiology; the structure and functions of the human body. London and New York, 1873.

39. BALFOUR, F. M.: Development of the uro-genital organs of vertebrates. Journal of anat. and physiology vol. x, part 1, 1875.

40. MAYER, F. J. C.: Ueber den Bau der Gehirns Fische in beziehung auf eine darauf gegründete Eintheilung dieser Thierklasse. Mit sieben Steintafeln: pp. 40. (Novorum Actorum * * * Naturæ Curiosorum. Tom. Vicesimus Secundus. 1864.)

41. MÜLLER, J.: Mémoire sur les Ganoïdes et sur la classification naturelle des poissons. Translated from Wiegmann's Archives, 1845. (Annales des sciences naturelles. 3me series, tome xiv. 1845, 5–53.)

42. VOGT, CARL: Quelques observations sur les caractères qui servent a la classification des poissons ganoïdes. (Annales des sciences naturelles, t. xiv, 1845, 53–68; with 1 plate.)

43. FOSTER AND BALFOUR: The elements of embryology. 16mo, pp. 272, 71 figures, London, 1874.

44. LANGERHANS, PAUL: Zur Anatomie des *Amphioxus lanceolatus*. (Archiv für kroskopische Anatomie, Band xii, zweites heft, 1875; pp. 290–348; Taf. xii–xv.)

45. MIKLUCHO-MACLAY. Beitrag zur vergleichenden Anatomie des Gehirns. pp. 19, 3 fig. (Jenaischen Zeitschrift für medicin und Naturwissenschaft. 1868.)

46. GÜNTHER, A.: *Ceratodus* and its place in the system. pp. 5, 2 figs. (Annals and magazine of natural history, 1871. vii, 222–227.)

47. HUXLEY, T. H.: On *Ceratodus*. (Proceedings zoöl. soc. London, Jan. 4, 1876.) [Mentioned in "Nature," Jan. 6.]

48. AGASSIZ, LOUIS: Contributions to the natural history of the United States; quarto, 4 vols.

EXPLANATION OF PLATE I.[20]

Fig. 1. Young *Lepidosteus* 18mm. in length, enlarged 5 diameters. The tip of the tail is missing, and its supposed form is indicated by the dotted outline. *N*, the nostrils of the left side; the anterior one is more nearly upon the upper surface than in the adult. In the margins of the jaws appear slight elevations, probably teeth. *O*, the operculum; *P*, the pectoral fin consisting of a rounded fleshy lobe *L* and a thin fringe *F*; 1, 2, 3, 4, 5, regions of the primordial median fin. *V*, the vent. *C*, the commencement of the infra-caudal lobe. The commencing anal is seen between *V*, and *L*. *D*, the commencing dorsal fin; *X*, indicates a slight and transitory modification of the primordial fin like a second dorsal, or, more probably, supra-caudal lobe. The ventrals have not appeared. The lines above figures 1, 2, 3 indicate the actual length of the young *Lepidosteus*.

Fig. 2. Tail of young *Lepidosteus* 22mm. in length, enlarged 4 diameters. The lettering as in fig. 1. The infra-caudal (*C*) begins to project beyond the outline of the primordial fin. *Ve* the ventral fin.

Fig. 3. Tail of young *Lepidosteus* 44mm. in length, enlarged 2 diameters. Lettering as in fig. 2. The primordial fin exists only upon the borders of the filamentary termination of the body (*Fl*) which is now crowded up by the increasing infra-caudal lobe.

Fig. 4. Tail of young *Lepidosteus osseus* 300mm. long, natural size. The infra-caudal lobe now occupies its permanent place as the functional tail, while the filament (*Fl*) has nearly disappeared. Its base is protected by six pair of fulcra (*DF*) and a similar series covers the anterior half of the lower border of the tail (*VF*).

Fig. 5. Dissected tail of medium sized *Lep. platystomus*. The filament has disappeared and the fulcra extend backward to a point nearly corresponding with its separation from the caudal fin. To this point may be traced a cartilaginous rod (*N*), the prolongation of the vertebral column (*VC*), and previously continued into the filament. This rod consists of the notochord, the spinal cord (*SC*), and a cartilaginous sheath. *NC*, neural canal laid open. *HC*, hæmal canal, laid open.

Fig. 6. Section of the upper margin of the tail of *L. platystomus* at a point about mid-way between the base of the fin and the last pair of fulcra; enlarged. *N*, notochord; *SC*, spinal cord; *CS*, cartilaginous sheath, in which the vertebræ are afterward developed. *F''*, points of the upper fulcra; *F'*, cut surfaces of the next lower fulcra; *F*, cut surfaces of the lowest fulcra which are separated so as to embrace the upper half of the cartilage. *CR'*, cut surface of the uppermost caudal fin ray, the two halves being separated above to enclose the lower part of the cartilage. The dark line crossing the section indicates the commencing splitting of the ray into two. *CR*, the halves of the second fin ray not quite perfectly apposed, and joined by a double membrane to the rays above and below.

[20] All the figures were drawn, from specimens and preparations, by Mr. Philip Barnard.

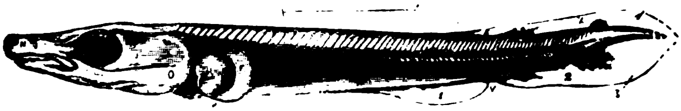


Fig. 1. Young Lepidosteus, enlarged 5 diameters.

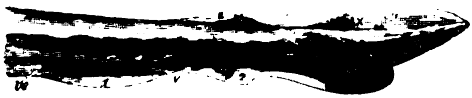


Fig. 2. Tail of young Lepidosteus, enlarged 4 diameters.

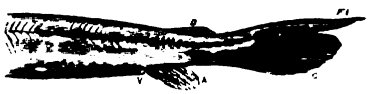


Fig. 3. Tail of young Lepidosteus, enlarged 2 diameters.

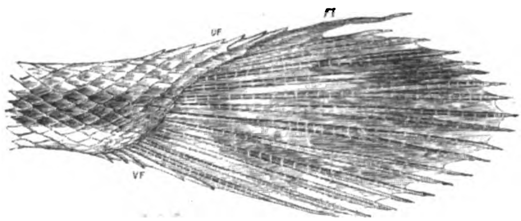


Fig. 4. Tail of young Lepidosteus, natural size.

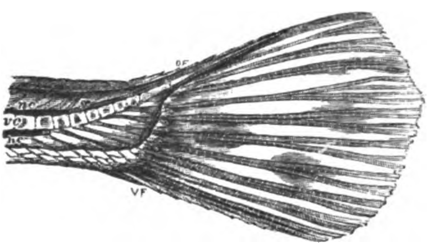


Fig. 5. Tail of adult Lepidosteus platystomus, one-half natural length; dissected.

Fig. 6. Section of notochord and the surrounding parts.

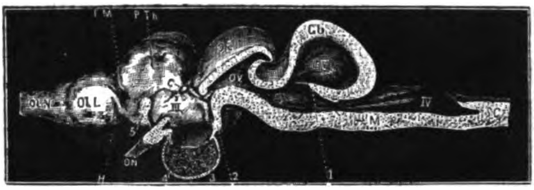


Fig. 7. Lepidosteus. Mesial, vertical, longitudinal section of brain, enlarged two diameters.

FM

H

Fig. 8. Amia.

FM

H

Fig. 9. Acipenser.

FM

H

Fig. 10. Polyodon.

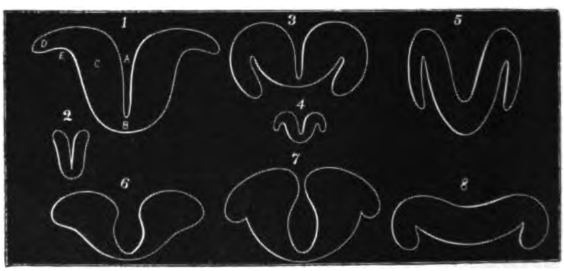


Fig. 11. Cross sections of Prothalami of Ganoids.

EXPLANATION OF PLATE II.

Fig. 7. Vertical longitudinal section of the brain of *Lepidosteus osseus*. The specimen was a female, about four and one-half feet long. The figure is enlarged two diameters. The cut surfaces are dotted. *SC*, spinal cord; *M*, medulla oblongata; *IV*, fourth ventricle; *Cb*, cerebellum; *CV*, ventricle of the cerebellum; 1, anteverted posterior border of the cerebellum; behind this is seen the low ridge referred to in the text; *AS*, aqueduct of Sylvius, or passage from the fourth ventricle into that of the optic lobes; *OL*, optic lobe; *OV*, optic ventricle; *C*, conarium or pineal body just in front of the opening of the optic ventricle; *III*, third ventricle opening downward into the hypoaria or *lobi inferiores*, which may represent the *corpora cinerea* of anthropotomy; 2, the thickened hinder wall of this cavity; 3, the hypophysis or pituitary body, apparently vascular and easily detached; a narrow longitudinal slit communicates with the cavity above; 4, the optic chiasma, forming part of the anterior wall of the hypoarian ventricle; *ON*, the right optic nerve; *PTH*, the right prothalamus (usually called hemisphere): 5, commissure connecting the prothalami; it is connected with the optic chiasma by a thin lamina forming part of the floor of the ventricle; *FM*, the foramen of Monro; *H*, a raised margin of this orifice, which is more apparent in the other brains, and may be a rudimentary hemisphere; *OlL*, olfactory lobe, containing a ventricle which communicates through the foramen of Monro with the third or median ventricle between the prothalami of opposite sides. In *Amia*, *Acipenser* and *Polyodon* the optic lobe is connected with the prothalamus by a lower rounded crus thalami on each side; but as the ganoid nature of these genera is denied by some, I chose the brain of *Lepidosteus*, although it is less well adapted to display all the parts.

Figs. 8, 9, 10. Mesial surface of the right olfactory lobe and nerve, the hemisphere, foramen of Monro and anterior part of the prothalamus of *Amia*, *Acipenser* and *Polyodon*; enlarged two diameters. The letters as in Fig. 7.

Fig. 11. Transverse sections of the prothalami enlarged two diameters. These figures are somewhat diagrammatic, but they indicate the facts that the lateral masses (*C*) are solid, with dorsal borders (*D*) more or less everted, so as to form an external concavity (*E*); that they are connected by a ventral commissure (*B*) and that between them (*A*) is a space, the median or third ventricle. 5, *Polypterus* (from Müller); 3, *Amia*; 4, young *Amia*, 70$^{mm.}$ in length; 1, *Lepidosteus osseus*; 2, young *Lepidosteus*, 300$^{mm.}$ in length; 6, *Polyodon*; 7 and 8, *Acipenser rubicundus*, at two different points and angles.

EXPLANATION OF PLATE III.

Fig. 12. Diagrams intended to represent the structure of a ganoid brain as seen in longitudinal mesial section and in transverse sections through several parts. The letters as in Fig. 7.

Fig. 13. Diagrams representing the cross-section of the prothalami of Myzonts (*M*) and Selachians and of the hemispheres of Batrachians. The prothalamus of the adult Myzont is closed above, as in the embryo Selachian (*ES*). In the adult Selachian, by a deposition of matter the single cavity is filled up, excepting two lateral canals which converge backward to meet opposite the optic foramen, and diverge forward to enter the olfactory crura through the small hemispheres. In Ganoids, as seen in Fig. 11, the prothalamus is open above. Likewise in many, if not all, Teleosts, in which, however, the optic nerves form no chiasma. In Batrachians, as in the Dipnoans, the place of the prothalami is taken by a pair of true hemispheres, each containing a lateral ventricle.

Fig. 14. Anterior part of prothalamus of a perch (*Perca flavescens*), with the olfactory lobe and nerve, and the small foramen of Monro. (The dotted line makes the ventricle larger than it is really.) Enlarged ten diameters. The existence of the foramen in some Teleosts was ascertained after the paper was read. See page 184.

Fig. 15. Diagrams, slightly altered from Huxley, to indicate the typical structure of the brain in Batrachians, Reptiles, Birds and Mammals. The upper is a horizontal, the lower a vertical section. See page 175.

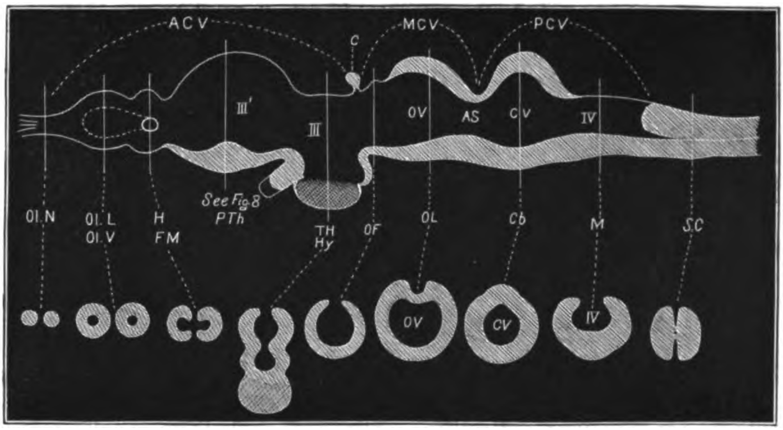


Fig. 12. Diagram of ganoid brain.

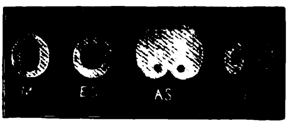


Fig. 13.

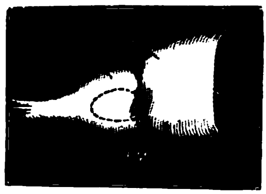


Fig. 14. Perca.

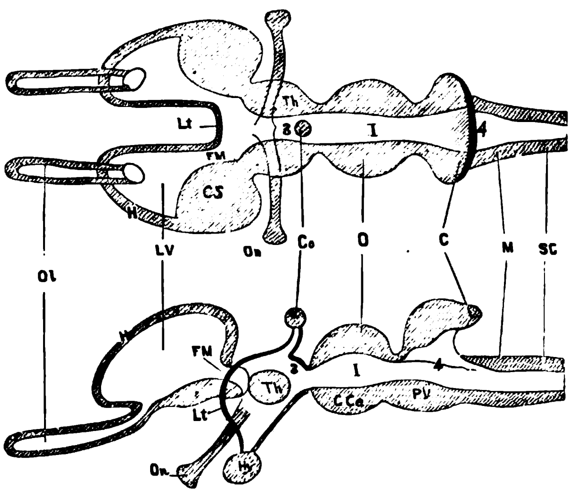


Fig. 15.

On the Distribution of Batrachia and Reptilia in North America. By E. D. Cope, of Haddonfield, N. J.

(ABSTRACT).

The discussion of this subject, of which the present paper is an abstract, is based on the large collections of the National Museum at Washington. In the first place, the primary divisions of the earth as proposed by Sclater and Huxley are redefined, and the mixture of South American families and genera in the North American fauna regarded as sufficient ground for separating it as a primary division, from Europe-Asia. The subdivisions or regions adopted, are six; two east of the plains, two on the central plateau, and two on the Pacific Coast. The first or Eastern, extends from the plains to the Atlantic, as far south as the isothermal of 77°; the Austroriparian extending from the Rio Grande to the Atlantic, south of the isothermal of 77°, extending up the Mississippi Valley to Indiana; third, the Central, extending from Texas and the Sierra Nevada to the eastern boundary of the plains; fourth, the Sonoran, embracing New Mexico, Arizona, and a part of Nevada; fifth, the Pacific, the region west of the Sierra Nevada; and lastly to the Lower Californian, covering the peninsula of that name. Of these, the Central is the poorest in reptilian life, the two eastern provinces are distinguished for the abundance of the species of salamanders and tortoises, and the Sonoran and Pacific, for the abundance of lizards. The Sonoran province is remarkably poor in salamanders and tortoises, while there are numerous salamanders, and but few tortoises in the Pacific district. The Austroriparian is the headquarters of tree-toads and moccasins; the Sonoran is the centre of variation of *Sceloporii*, horned and other lizards, rattlesnakes and toads. A great number of species is confined to this division. The snake-like batrachians belong exclusively to the Austroriparian district, the range of the genus *Siren* being co-extensive with its boundaries. A few Mexican genera extend east along the Gulf as far as Florida, and a few others of Sonoran character extend south into Mexico. The Lower Californian district is peculiar in its boæform serpents and large iguanas.

On the whole, the North American fauna is peculiar in its salamanders, old world in its frogs and most of its turtles, and South American in most of its snakes and lizards, and some of its turtles.

The distinction between the South American (neotropical) and North American (nearctic) fauna is as follows: Divisions belonging exclusively to the South American fauna: Pleurodire tortoises, Amphisbænian lizards, Scolecophid and Boid Snakes, and Cæciliid or worm-like *Batrachia*—five divisions. Those belonging to the North American fauna alone: Chelydrid tortoises, Urodele, Sirenoid, and Proteoid *Batrachians*, Raniform *Batrachia*—five divisions. The Mexican region, which is intermediate in position, is occupied by three of the divisions from each of the adjoining continents, viz.: Scolecophid and Boid snakes, Cæciliid, Urodele and Raniform Batrachia, and Chelydrid tortoises. Further than this, there are many genera especially developed in either the one or the other of the primary American faunæ, which extend for a greater or smaller distance into the other. Thus the genera of lizards and many of the snakes of Southern North America, extend to the city of Mexico; others extend to Tehuantepec; others to Guatemala and Costa Rica, and two to Panama. Vice versa, each of these and other points of latitude, mark the northern boundaries of distribution of South American species and genera. Besides, numerous genera are peculiar to Mexico alone.

Several hypotheses explaining the relation of life to distribution and surroundings may be entertained. It may be supposed that its present phenomena are due to the operation of physical causes, or are the results of symmetrical or numerical laws; or are due to a power of self-direction possessed by living beings; possibly by all these influences combined. The actual relations between the structure of animals and the physical features of the regions which they inhabit must obviously be ascertained at the outset of the inquiry. It may be observed that the characteristics of the *Batrachia* and *Reptilia* are such as to make them especially useful in the inquiry. Their cold blood, incapable of resisting the extremes of temperature, renders them peculiarly susceptible to its influences, while the fact that the *Batrachia* are semi-aquatic, requiring water for the maintenance of the reproductive function, renders them amenable to conditions of humidity. In the faunal divisions of the globe the conformity of the indications exhibited by the animals in question to those derived from other divisions of the animal kingdom is very evident.

Without giving lists of the species and genera characteristic of the regions of the Nearctic realm, the general conclusions are as follows; and first as to temperature.

The first observation with regard to the Batrachian and Reptilian fauna of North America is the usual one, viz., that the number of specific and generic types exhibits a rapid increase as we approach the tropics. Of the area inhabited by these forms of animals, less than one-fourth is included in the three Southern regions—the Austroriparian, the Sonoran, and the Lower Californian; yet these contain more than half of the entire number of species, and all but eight of the genera are found in them. Of this number, forty-two genera, or one-third of the total, are confined to within their boundaries. It is a truism directly resulting from the very small production of animal heat by these animals, that temperature, and therefore latitude, has the greatest influence on their life and distribution. This is exhibited in other ways than in multiplication of forms. It is well known, that although plainly-colored reptiles are not wanting in the tropics, brilliantly-colored species are much more abundant there than in temperate regions. Although the Regnum Nearcticum does not extend into the tropics, its southern districts are the habitat of most of the species characterized by bright colors. This is most instructively seen in species having a wide range. Such is the case with the southern subspecies of *Desmatognathus* among salamanders, and *Hyla* among frogs. So with snakes of the genera *Crotalus*, *Caudisona*, *Ophibolus*, *Bascanium*, and *Eutaenia*. It is also true of the lizards of the genera *Phrynosoma*, *Holbrookia*, and *Sceloporus*. *Eutaenia* and *Sceloporus* become metallic in the Mexican subregion, as is also the case with the Anoles. The North American species of *Anolis* does not display metallic luster, while a large part of those of Mexico and a smaller proportion of those of the West Indies exhibit it.

To the north the distribution also exhibits relation to temperature. The eastern region is divided into the Carolinian, Alleghanian, and Canadian districts. No reptiles are found north of the Canadian district, while five species and subspecies of *Batrachia* are nearly confined to it. It extends down the crests of the Alleghany Mountains to Georgia.

In Central America and Mexico it is the central plateau and the high mountains which support the North American forms, while the South American genera and species are distributed along the Tierra Caliente of the east and west coasts. Thus it is evident that temperature has a controlling influence in the distribution of reptilian life on the North American continent.

The other important influence in the modification of the life in question is the amount of terrestrial and atmospheric moisture. In the case of the Batrachia, this agent is as important as that of heat, since a greater or less part of their life is, in most species, necessarily spent in the water. The reptiles are less dependent on it, but, as their food consists largely of insects, and as these in turn depend on vegetation for sustenance, the modifying influence of moisture on their habits must be very great.

The central region combines the disadvantages of low temperature, due to its elevation above the level of the sea, and of arid atmosphere; hence its poverty in *Batrachia* and *Reptilia*. There are but nine species of both classes peculiar to it, while a few others enter from surrounding areas.

The distribution in the other regions is evidently dependent on the same conditions. Thus the well-watered, forest-covered Eastern and Austroriparian regions are the home of the salamanders, the frog, the tree-toads, and the turtles. The dry and often barren Sonoran and Central regions abound in the lizards and the toads. The Pacific region, which is intermediate in climatic character, exhibits a combination of the two types of life; it unites an abundant lizard-fauna with numerous frogs and salamanders, while there is but one tortoise.

The influence of humidity is seen in the almost entire exclusion of *Batrachia* and *Reptilia* from the arid regions of the Central and Sonoran districts, and their abundance in the East; and in the substitution of these animals in the former regions by the lizards, those lovers of deserts and sands. The same influence is observed in the distribution of these animals on the plains and mountains of Mexico. As is well known, the trade winds from the Caribbean Sea, laden with moisture, strike the Cordilleras on the eastern slope and rise to the cooler altitudes, where precipitation takes place. The rainfall at an elevation of from five to seven thousand feet in Costa Rica, according to Dr. Gabb, is very great, occupying at least 200 days in the year, many of the remaining days being foggy. The western side of the Cordilleras is comparatively dry. The wet belt is found to be the especial habitat of *Batrachia;* the proportion of species being: lizards, none; snakes, three; *Batrachia*, sixteen species, while the proportion of individuals in favor of the Batrachia, is much greater. The lizards are abundant in the low country, and the majority of the snakes occur there also, with a proportion of the *Batrachia.*

Another character of the reptilian life of arid regions is to be seen in a peculiarity of coloration.[1] This, which has been already observed by the ornithologists, consists of a pallor, or arenaceous hue of the body, nearly corresponding with the tints of dry or sandy earth. This prevails throughout the Batrachia and Reptilia of the Sonoran region, although it is often relieved by markings of brilliant color, of which red is much the most usual.

Another peculiarity of the Sonoran region, and which it shares with a part of Mexico, is the predominance of snakes which possess an extraordinary development of the rostral shield either forward or outward. This has also been observed by Professor Jan, who referred such genera to a group he termed the *Probletorhinidæ.* Of ten genera of snakes in the Nearctic region which possess the character, nine are found in the Sonoran subregion, five are peculiar to it, and it shares two with the Lower Californian subregion only. One of the latter (*Phimothyra*) is closely imitated by a genus (*Lytorhynchus*) which occurs on the borders of the African Sahara. The *Heterodon* of the Eastern States, though not confined to the sandy coast-regions, greatly abounds there; and the South American species skip the forest-covered Amazon Valley and reappear on the plains of the Paraguay and Parana. As the Sonoran region embraces a number of desert areas, it is altogether probable that the peculiar forms in question have a direct relation to the removing of dry earth and sand, in the search for concealment and food. A modification of foot-structure, supposed to have relation to the same end, is seen in the movable spines on the outer side of the foot in the genus *Uma*, a character exhibited in higher perfection in the South African genus *Ptenopus.*[2]

The abundance of Bufones is doubtless due in part to their adaptation to life in dry regions. They are mostly furnished with tarsal bones especially developed for excavating purposes.

It would, therefore, appear that temperature exercises the greatest influence on reptilian life, and that conditions of humidity are effective in determining the distribution of *Batrachia* and *Reptilia.*

[1] Origin of Genera, 1869, p. 68.
[2] Proc. Acad. Phila., 1868, p. 321.

On the Method of Subduing Insects Injurious to Agriculture. By John L. LeConte, of Philadelphia, Penn.

In accordance with predictions made at the time of its first appearance in the immediate valley of the Mississippi, the Colorado potato-beetle continues to extend its area of distribution. It has during the last and present seasons reached the Atlantic coast of the Middle States, and is preparing an invasion in mass of the maritime parts of New England, which will soon be overrun with the same ease with which it has conquered the Western and Middle States.

Meanwhile the farmers are anxiously enquiring for means of destroying the invader; and are receiving through the agricultural columns of the newspapers many suggestions, some of which are good, some of which are very questionable.

Materials destructive to the insects, and said not to be injurious to the plant or the soil have been recommended, almost without number; but with the exception of Paris green, they have been either very insufficiently tried, or found inoperative.

That compound of arsenic and copper therefore remains, naturally, the favorite, notwithstanding its dangerous qualities, and the possibly deleterious effect it may produce on the fields after long use.

Entomologists and other scientific men are often asked: Why do you not give us another remedy against this destructive insect? Are you baffled with all your boasted progress in learning by the invasion of a wretched little bug?

No my friends, we are not baffled by the wretched little bug, but in our endeavors to teach you how to dispose of it, in such manner as to protect your crops, we are embarrassed by your own failure to grasp the magnitude of the problem which you have set us to solve. Had you, indeed, comprehended the warnings given by my lamented friend B. D. Walsh, on the first injurious appearance of the insect, and since repeated by many entomologists, you would have insisted several years ago, that the subject should be investigated with a power of enquiry proportioned to its importance, and you would have received such information as might, with proper and well-directed industry on your part, have prevented much loss.

However, I do not wish now to speak of the past; it is gone,

and its errors cannot be undone. Let us rather enquire what shall be done in the future.

The first thing then, is to cease calling upon Science for a remedy, when Science and Empiricism have already given you probably many remedies, concerning the application of which I will have a word to say, bye and bye.

Science, like Hercules in the old fable of the wagoner, can help you, and will help you, only when you have commenced to help yourselves.

How then can we begin to help ourselves? I hear you ask. That is precisely what I will briefly endeavor to tell you.

First then: There should be a scientific commission, selected by competent scientific authority, for their merit, and not for their political influence. Politicians have had too much control over our agricultural interests, as you all have reason to remember with regret.

This commission should be sufficiently large to subdivide the subjects committed to them, in such manner, as to thoroughly investigate the habits and times of appearance in different districts, of the great agricultural pests; the effects upon them of all the cheaper materials which have been, or may be judiciously suggested as destroying agents, and the proper times and manner of applying them. The members of the commission should also receive sufficient compensation to warrant them in giving as much time and labor to this investigation as may be required, even to the temporary abandonment, if necessary, of their other scientific or secular pursuits.

No such task can be properly performed and completed by the solitary labors of State Entomologists, underpaid and over-burdened with work. Only by association of several such careful observers and investigators can a worthy and useful result be obtained for the suppression of several of the most formidable pests.

Second: This information being procured, should be tabulated as far as possible, or at least, reduced to a compact form, for easy reference, and widely published in newspapers, and also in pamphlet form, for universal distribution.

Third: By the distribution of this information, and by appeals through the newspapers and agricultural journals, as well as by addresses at meetings of farmers, and others interested in agriculture, it must be impressed upon the public mind, that all individual

efforts for the suppression of these pests are frequently futile. Only combined and consentaneous action over large tracts of country will be effective.

Now, while I am prepared to believe, that when these facts are made known to the farmers, they will immediately see the importance of the suggestion for unanimous and simultaneous advance upon the enemy, yet, without legislative aid it will be quite impossible to secure the organization requisite for an effective onslaught.

It will, therefore, be necessary for the citizens, thus instructed, to command their representatives either in State Legislatures, or in National Congress, to prepare proper laws for the destruction of these pests, at stated times, to be determined and recommended by the scientific commission.

These laws will be not only cheerfully obeyed by every intelligent farmer, but I know that the farmers as a class will be glad to have such laws enacted, and enforced with penalties for neglect.

Those disposed to help themselves and each other, can only thus be protected against an ignorant or indolent neighbor, whose thriftlessness would otherwise make of his potato-patch, his cotton-field, or his plum-orchard, a nuisance nursery, from which no industry could protect the surrounding farms.

Thus then, the organization necessary for a successful campaign against our insect-enemies must be authoritatively demanded by you. Under less free forms of government, the plan I have suggested above would probably have long ago been perfected by the rulers. Even the fear of the extension of the Colorado potato-beetle to Europe has excited in several countries almost as much discussion and confusion of counsel as an apprehended revolution.

You will also see, in an interesting paper "on the means of destroying the Grasshopper" by the late Col. Motschulsky, (translated and published in the Smithsonian Report, 1858), that in the Province of New Russia not less than 80,000 men were employed in destroying locusts during an invasion which occurred in 1855. He adds: "the labor, however, was ineffective, as the locusts had been permitted to develop too far before the attack was commenced.

The fact is, that these incursions and ravages of hostile insects represent a condition of *war*. It is only by a quasi-military organization, and appropriate weapons, suited to the nature of the

enemy that they can be conquered. Without recognition of this fact, nothing can be done against them, and we must bow our heads, and exclaim, with the pious Mahommedan fatalist, "it is the will of God."

Three subjects yet remain to be considered: the materials to be used; the time of making the attack in force; and the weapons to be employed.

1. The materials may be either mineral or vegetable, or merely human labor, intelligently and persistently applied. The latter is the only effective means of contending against some insects, but in all cases it is a necessary adjunct to the remedies used. These remedies, as I observed before, are very numerous, and until a careful investigation is made of the large number already suggested, which is increasing almost daily, no proper indications can be given, except that those least injurious to man should be preferred, even at greater cost of money and labor; and that those which kill the insect by contact with its body are likely to prove more effectual than those which destroy by poisoning its food. It may be here observed that the form of apparatus in these two cases must be quite different. In the latter, any contrivance which will sprinkle a fluid or dust a powder on the exposed or upper surface of the leaves will be sufficient: in the former, in which the poison kills by contact with the insect, it must be able to reach the enemy wherever sheltered.

2. The time of attack must naturally be when the enemy is least able to resist. To quote again from the excellent memoir of Motschulsky: "the most effective, and at the same time the easiest mode of opposing the development of the locusts is the crushing out of the young broods, when collected in swarms in the place where they are hatched. Consequently the most important thing is to know the resting place of these destructive pests. In order to discover them, and to point out the course to be pursued . . . . . it might be well to send skilful persons . . . . . to make the necessary researches; and these, with the assistance of the local authorities might seek out the places where the insects abound, and establish the necessary regulations for their destruction:" (l. c. p. 228.)

In the case of the cotton moths, it is plain that the attack should be made upon the earliest broods, which appear in the extreme southern part of the country, and from which the migrating

swarms which travel northward are developed: also that the attack must be directed against the caterpillars rather than the perfect insects.

The Colorado potato-beetle may be also attacked with greatest success in the larval state. The integuments are then soft, and the appetite more voracious; so that whether the poison by contact, or the poison by food be used, it will have a more certain effect, than upon the perfect insect, which is protected against the former by the hard chitinous surface, and against the latter by preoccupation in reproductive duties.

You will now be prepared to admit the importance of the recommendation above made, that the times for making the attack should be directed by the scientific commission, after full examination of the habits of the insects, and the dates of their appearance in their various stages of development: These dates will vary in different districts, and without a carefully tabulated calendar of the necessary facts, no system of combined effort, such as I believe to be essential, can be planned.

3. The apparatus to be used must of course vary greatly with the habits of the insect to be attacked. In the case of the plum Curculio, canvas frames, propelled on a kind of wheelbarrow, with a ram to concuss the trunk of the tree is probably the best instrument yet devised. The insects will fall into the net when the tree is struck, and may be easily destroyed, when a sufficient mass has been collected.

For the cotton moth and the potato-beetle, the apparatus for poisoning the leaves upon which they feed may be any simple sprinkler or dusting box, according as liquid or solid poison is employed.

But for direct application to the insect itself, we must use means by which a fine spray will be driven with force sufficient to envelop the whole plant, or the surface of the ground upon which the insects are assembled, in a mist of poisonous liquid.

Such an instrument is the atomizer: which has the additional advantage over a sprinkler, that it consumes less liquid.

The first application of the atomizer for the destruction of insects was made by me several years ago, and in the "American Naturalist" for August, 1869, I published a short paper recommending its use with certain poisonous liquids, for the disinfection and preservation of insect cabinets. I have personally

taught its application for that purpose to many friends, and in several museums both in this country and Europe; and the results have been in every way satisfactory, even the most delicate specimens being uninjured by the spray.

When the question of locusts became of importance last year, and the Colorado potato-beetle began to be very troublesome in the Atlantic States, I spoke with several commercial friends and others about the propriety of making atomizers of large size for the destruction of these pests. In consequence of delay in the measures they thought necessary to command the attention and security of a manufacturer, no progress has yet been made for introducing such a contrivance into general use. Meanwhile, a small apparatus, consisting of an atomizer, a bank of fluid supported on the back, and a pair of bellows fixed at the side of the operator has been independently introduced by a manufacturing establishment in Pennsylvania, and I have been told is somewhat of a favorite. It will doubtless be useful to a limited extent, and is I believe not patented.

I have now expressed to you my views concerning the organization and methods required for the subjugation of our most important insect foes.

The organization recommended can be effected only by the strong appeal of the people, where agricultural interests dominate, for proper instruction from the Government, and proper protection by legislative power. We have game laws to protect our useful wild animals; thistle laws to guard against extension of noxious weeds: why not have insect laws for destruction of agricultural pests?

Farmers of the West! are you willing to exert yourselves to procure this result? The prize is a rich one; it is no less than immunity from an annual destruction of property quadruple or sextuple that of the great Chicago conflagration.

LOCUSTS AS FOOD FOR MAN. By CHAS. V. RILEY, of St. Louis, Missouri.

IN the few words I have to communicate under this head, it is not my purpose to inflict a long dissertation on edible insects. The subject has been sufficiently treated of by various authors, and especially by Kirby and Spence in their admirable Introduction to Entomology; while, within the year, Mr. W. R. Gerard has brought together most of the facts in a paper entitled "Entomophagy," read before the Poughkeepsie Society of Natural History. It is my desire, rather, to demonstrate the availability of locusts as food for man, and their value, as such, whenever, as not unfrequently happens, they deprive him of all other sources of nourishment.

With the exception of locusts, most other insects that have been used as food for man, are obtained in small quantities, and their use is more a matter of curiosity than of interest. They have been employed either by exceptional individuals with perverted tastes, or else as dainty tit-bits to tickle some abnormal and epicurean palate. Not so with locusts, which have, from time immemorial, formed a staple article of diet with many peoples, and are used to-day in large quantities in many parts of the globe.

Any one at all familiar with the treasures on exhibition at the British Museum, must have noticed among its Ninevah sculptures, one in which are represented men carrying different kinds of meat to some festival, and among them some who carry long sticks to which are tied locusts—thus indicating that in those early days, represented by the sculpture, locusts were sufficiently esteemed to make part of a public feast. They are counted among the "clean meats" in Leviticus (xi: 22), and are referred to in other parts of the Bible, as food for man. In most parts of Europe, Asia and Africa, subject to locust ravages, these insects have been, and are yet, extensively used as food. Herodotus mentions a tribe of Æthiopians "which fed on locusts which came in swarms from the southern and unknown districts," and Livingstone has made us familiar with the fact that the locust-eating custom yet prevails among many African tribes. Indeed, some tribes have been called *Acridophagi*, from the almost exclusive preference they give to this diet. We have it from Pliny that locusts were in high esteem among the Parthians, and the records

of their use in ancient times, as food, in southern Europe and Asia, are abundant. This use continues in those parts of the world to the present day.

In Morocco, as I am informed by one (Mr. Trovey Blackmore, of London) who has spent some time in that country, they do more or less damage every year, and are used extensively for food whenever they abound so as to diminish the ordinary food-supply; while they are habitually roasted for eating and brought into Tangier and other towns by the country people, and sold in the market places and on the streets. The Jews, who form a large proportion of the population, collect the females only for this purpose—having an idea that the male is unclean, but that under the body of the females there are some Hebrew characters which make them lawful food. In reality there are, under the thorax, certain dark markings—the species used, and which is so injurious to crops, being the *Acridium perigrinum.* Radoszkowski, President of the Russian Entomological Society, tells me that they are also, to this day, extensively used as food in southern Russia; while many of our North American Indian tribes, and notably the Snake and Digger Indians of California, are known to feed upon them. No further evidence need be cited to prove the present extensive use of these insects as articles of food. Let us then briefly consider the nature of this locust food and the different methods of preparing it.

The records show us that in ancient times these insects were cooked in a variety of ways. *Œdipoda migratoria* and *Acridium perigrinum*, which are the more common devastating locusts of the "old World," are both of large size, and they are generally prepared by first detaching the legs and wings. The bodies are then either boiled, roasted, stewed, fried or broiled. The Romans are said to have used them by carefully roasting them to a bright golden yellow. At the present day, in most parts of Africa, and especially in Russia, they are either salted or smoked like red herrings. Chenier, in his account of the Empire of Morocco (London, 1788), says that thus cured, they are brought into the market in prodigious quantities, but that they have "an oily and rancid taste, which habit only can render agreeable." The Moors use them, to the present day, in the manner described by Jackson in his "Travels in Morocco," viz.: by first boiling and then frying them: but the Jews, in that country—more provident than

the Moors — salt them and keep them for using with the dish called *Dafina*, which forms the Saturday's dinner of the Jewish population. The dish is made by placing meat, fish, eggs, tomatoes — in fact, almost anything edible — in a jar which is placed in the oven on Friday night, and taken out hot on the Sabbath, so that the people get a hot meal without the sin of lighting a fire on that day. In the Abbe Godard's "*Description et Histoire de Maroc*," (Paris, 1860), he tells us that, "they are placed in bags, salted, and either baked or boiled. They are then dried on the terraced roofs of the houses. Fried in oil they are not bad." Some of our Indians collect locusts by lighting fires in the direct path of the devouring swarms. In roasting, the wings and legs crisp up and are separated, the bodies are then eaten fresh or dried in hot ashes and put away for future use. Our Digger Indians roast them, and grind or pound them to a kind of flour, which they mix with pounded acorns, or with different kinds of berries, make into cakes and dry in the sun for future use.

The species employed by the ancients were doubtless the same as those employed at the present day in the East, viz.: the two already mentioned, and to a less degree, the smaller *Caloptenus Italicus*. We have no records of any extended use of our own Rocky Mountain species (*Caloptenus spretus*), unless—which is not improbable — the species employed by the Indians on the Pacific coast, should prove to be the same, or a geographical race of the same.

It had long been a desire with me to test the value of this species (*spretus*) as food, and I did not lose the opportunity to gratify that desire which the recent locust invasion into some of the Mississippi Valley states offered. I knew well enough that the attempt would provoke to ridicule and mirth, or even disgust, the vast majority of our people, unaccustomed to anything of the sort, and associating with the word insect or "bug," everything horrid and repulsive. Yet I was governed by weightier reasons than mere curiosity; for many a family in Kansas and Nebraska was last year brought to the brink of the grave by sheer lack of food, while the St. Louis papers reported cases of actual death from starvation in some sections of Missouri, where the insects abounded and ate up every green thing, the past spring.

Whenever the occasion presented I partook of locusts prepared

in different ways, and, one day, ate of no other kind of food, and must have consumed, in one form and another, the substance of several thousand half-grown locusts. Commencing the experiments with some misgivings, and fully expecting to have to overcome disagreeable flavor, I was soon most agreeably surprised to find that the insects were quite palatable, in whatever way prepared. The flavor of the raw locust is most strong and disagreeable, but that of the cooked insects is agreeable, and sufficiently mild to be easily neutralized by anything with which they may be mixed, and to admit of easy disguise, according to taste or fancy. But the great point I would make in their favor is, that they need no elaborate preparation or seasoning. They require no disguise, and herein lies their value in exceptional emergencies; for when people are driven to the point of starvation by these ravenous pests, it follows that all other food is either very scarce or unattainable. A broth, made by boiling the unfledged *Calopteni* for two hours in the proper quantity of water, and seasoned with nothing in the world but pepper and salt, is quite palatable, and can scarcely be distinguished from beef broth, though it has a slight flavor peculiar to it and not easily described. The addition of a little butter improves it, and the flavor can, of course, be modified with mint, sage, and other spices, *ad libitum*. Fried or roasted in nothing but their own oil, with the addition of a little salt, and they are by no means unpleasant eating, and have quite a nutty flavor. In fact, it is a flavor, like most peculiar and not unpleasant flavors, that one can soon learn to get fond of. Prepared in this manner, ground and compressed, they would doubtless keep for a long time. Yet their consumption in large quantities in this form would not, I think, prove as wholesome as when made into soup or broth; for I found the chitinous covering and the corneous parts — especially the spines on the tibiæ — dry and chippy, and somewhat irritating to the throat. This objection would not apply, with the same force, to the mature individuals, especially of larger species, where the heads, legs and wings are carefully separated before cooking; and, in fact, some of the mature insects prepared in this way, then boiled and afterward stewed with a few vegetables, and a little butter, pepper, salt and vinegar, made an excellent fricassee.

Lest it be presumed that these opinions result from an unnatural palate, or from mere individual taste, let me add that I took pains

to get the opinions of many other persons. Indeed, I shall not soon forget the experience of my first culinary effort in this line — so fraught with fun and so forcibly illustrating the power of example in overcoming prejudice. This attempt was made at an hotel. At first it was impossible to get any assistance from the followers of the *ars coquinaria*. They could not more flatly have refused to touch, taste or handle, had it been a question of cooking vipers. Nor love nor money could induce them to do either, and in this respect the folks of the kitchen were all alike, without distinction of color. There was no other recourse than to turn cook myself, and operations once commenced, the interest and aid of a brother naturalist and two intelligent ladies were soon enlisted. It was most amusing to note how, as the rather savory and pleasant odor went up from the cooking dishes, the expression of horror and disgust gradually vanished from the faces of the curious lookers-on, and how, at last, the head cook — a stout and jolly Negress — took part in the operations; how, when the different dishes were neatly served upon the table and were freely partaken of with evident relish and many expressions of surprise and satisfaction by the ladies and gentlemen interested, this same cook was actually induced to try them and soon grew eloquent in their favor; how, finally, a prominent banker, as also one of the editors of the town joined in the meal. The soup soon vanished and banished silly prejudice; then cakes with batter enough to hold the locusts together disappeared and were pronounced good; then baked locusts with or without condiments; and when the meal was completed with dessert of baked locusts and honey *a la* John the Baptist, the opinion was unanimous that that distinguished prophet no longer deserved our sympathy, and that he had not fared badly on his diet in the wilderness. Prof. H. H. Straight, at the time connected with the Warrensburg (Mo.) Normal School, who made some experiments for me in this line, wrote: "We boiled them rather slowly for three or four hours, seasoned the fluid with a little butter, salt and pepper, and it made an *excellent* soup, *actually;* would like to have it even in prosperous times. Mrs. Johonnot, who is sick, and Prof. Johonnot pronounced it excellent."

I sent a bushel of the scalded insects to Mr. Jno. Bonnet, one of the oldest and best known caterers of St. Louis. Master of the mysteries of the cuisine, he made a soup which was really

delicious and was so pronounced by dozens of prominent St. Louisians who tried it. Shaw, in his *Travels in Barbary* (Oxford, England, 1738), in which two pages are devoted to a description of the ravages of locusts, mentions that they are sprinkled with salt and fried, when they taste like crawfish; and Mr. Bonnet declared that this locust soup reminded him of nothing so much as crawfish bisque, which is so highly esteemed by connoisseurs. He also declared that he would gladly have it on his bill of fare every day if he could get the insects. His method of preparation was to boil on a brisk fire, having previously seasoned them with salt, pepper and grated nutmeg, the whole being occasionally stirred. When cooked they are pounded in a mortar with bread fried brown, or a puree of rice. They are then replaced in the saucepan and thickened to a broth by placing on a warm part of the stove, but not allowed to boil. For use, the broth is passed through a strainer and a few croutons are added. I have had a small box of fried ones with me for the past two months, and they have been tasted by numerous persons, including the members of the London Entomological Society and of the *Society Entomologique de France*. Without exception they have been pronounced far better than was expected, and those fried in their own oil with a little salt are yet good and fresh; others fried in butter have become slightly rancid—a fault of the butter. Mr. C. Horne, F. Z. S., writing to *Science-Gossip* about swarms of locusts which visited parts of India in 1863, says; "In the evening I had asked two gentlemen to dinner and gave them a curry and croquet of locusts. They passed for Cabul shrimps, which in flavor they much resembled, but the cook having inadvertently left a hind leg in a croquet, they were found out, to the infinite disgust of one of the party and the amusement of the other."

This testimony as to the past and present use of locusts as human food might be multiplied almost indefinitely, and I hope I have said enough to prove that the nature of that food is by no means disagreeable. In short, not to waste the time of the association in further details, I can safely assert, from my own personal experience, that our Rocky Mountain locust is more palatable when cooked than some animals that we use on our tables. I mention the species more particularly, because the flavor will doubtless differ according to the species, or even according to the nature of the vegetation the insects were nourished on.

I have made no chemical analysis of this locust food, but that it is highly nourishing may be gathered from the fact that all animals fed upon the insects thrive when these are abundant; and the further fact that our locust-eating Indians, and all other locust-eating people, grow fat upon them.

Locusts will hardly come into general use for food except where they are annually abundant, and our Western farmers who occasionally suffer from them will not easily be brought to a due appreciation of them for this purpose. Prejudiced against them; fighting to overcome them, killing them in large quantities, until the stench from their decomposing bodies becomes at times most offensive—they find little that is attractive in the pests. For these reasons, as long as other food is attainable, the locust will be apt to be rejected by most persons. Yet the fact remains that they do make very good food. When freshly caught in large quantities, the mangled mass presents a not very appetizing appearance, and emits a rather strong and not over pleasant odor; but rinsed and scalded, they turn a brownish red, look much more inviting, and give no disagreeable smell.

The experiments here recorded have given rise to many sensational newspaper paragraphs, and I consider the matter of sufficient importance to record the actual facts, which are here given for the first time.

Like or dislike of many kinds of food are very much matters of individual taste or national custom. Every nation has some special and favorite dish which the people of other nations will scarcely touch, while the very animal that is highly esteemed in one part of a country is not unfrequently rejected as poisonous in another section. We use many things to-day that were considered worthless or even poisonous by our forefathers. Prejudice wields a most powerful influence in all our actions. It is said that the Irish during the famine of 1857, would rather starve than eat corn-bread; and if what I have here written shall, in the future, induce some of our Western people to profit by the hint, and avoid suffering from hunger or actual starvation, I shall not have written in vain.

THE LOCUST PLAGUE; HOW TO AVERT IT. By C. V. RILEY, of St. Louis, Mo.

FOR three years past the attention of the nation has been attracted to the fearful ravages of locusts, or so-called "grasshoppers," in much of the fertile country between the Mississippi and the Rocky Mountains. These ravages have been committed by a single species—the *Caloptenus spretus* Thomas, or Rocky Mountain locust. Insignificant, individually, but mighty in its collective power for evil, it has so far baffled the efforts of an intelligent and powerful nation to subdue it. In 1873 Minnesota and Iowa were sorely afflicted by this pest, and appealed to the nation for assistance in relieving the consequent suffering in their western counties. In 1874 the ravages of this insect were so extended and so serious in several of the Western States, but especially in Nebraska and Kansas, that even the efforts of the state authorities, and the generous assistance of the people of the whole Union, were insufficient to prevent a vast amount of suffering and destitution. And during the present year, in these same States and in the western part of Missouri, we have had a repetition of these fearful ravages, with even greater intensity. Some of the more fertile States of the Union have, in short, been smitten by a plague of locusts which, in the amount of injury caused, and the amount of suffering produced, as well as in all its essential manifestations, was a repetition of those visitations that have occurred in the Old World from time immemorial, and which have been so graphically described by ancient and modern authors. Indeed, there are few of the members of this Association, unless they have had personal experience of the facts, who can form any just conception of the utter destitution that often follows the wake of this pest. State legislatures have been convened in extra session to consider the best means of allaying the want and suffering caused by the insect. Hundreds of thousands of dollars have been either donated by individuals or appropriated by municipal authorities for this purpose; and very justly too, since, when such a calamity befalls any portion of the community, the more favored portion should feel morally bound to relieve the distress.

Yet, though so much has been expended to palliate the evil, and the governor of my own State, from the gravity of the situation, felt it incumbent upon him to proclaim the 3d of June as a

day of fasting, humiliation and prayer, in order that the Almighty might be supplicated to rid the people of the plague; no special effort has been made—not a single dollar specially expended—to prevent a recurrence of the evil. I have said that this locust has so far baffled the efforts of an intelligent nation to subdue it; I should have said, rather, that no serious and intelligent efforts have been made to subdue it. We have a Department of Agriculture, which is supported by large appropriations made annually by congress, and I have yet to learn that the commissioner at the head of that Department has made any effort to study or subdue the locust plague, or—supposing the means are not at hand to enable him to cause the proper studies and experiments to be instituted—that he has ever appealed to congress for means to this end.

In my limited, individual capacity, I have given some study to the insect, and the burthen of my remarks will be to show that from present knowledge, we already have the power to materially check the evil; and that a few thousand dollars expended in further research and experiment might give us entire control over it.

The means to be employed against the ravages of this insect in the more fertile country subject to its periodical visitations, but in which it is not indigenous, may be classed under five heads: 1. Natural agencies; 2. Artificial means of destroying the eggs; 3. Such means of destroying the unfledged young; 4. Remedies against the mature or winged insects; 5. Prevention. With the exception of the last, these measures have already been considered by me in the seventh Missouri Entomological Report, and in the columns of "The New York Tribune." I shall therefore barely enumerate them in this connection.

1. *Natural Agencies.*—These are 1st, climatic conditions which induce disease and prevent the insect's continued multiplication in much of the country it invades; 2d, natural enemies, consisting of birds, reptiles and mammals which devour, or in other ways destroy it, and of predaceous and parasitic species of its own class. The agencies in the first and last categories are measurably beyond man's control, and will do their appointed work uninfluenced by his action; but the others are more within his control. Almost all birds inhabiting the Western plains, feed upon the locust and its eggs, and the prairie chicken and quail

are untiring in this good work. The States subject to locust ravages should pass more stringent laws for the better protection of these game birds, with which the markets of the East are annually glutted. Many of the harmless reptiles—toads, snakes and lizards—should be spared from the ruthless war which most persons, ignorant of their habits, wage against them. They will only be so spared when natural history shall have acquired its due importance in our schools, and every farmer's child shall understand the habits of the animals, both large and small, with which, in after life, it is likely to come in contact, so as at least to be able to discriminate between those which are harmless or beneficial, and those which are injurious. Of the use that can be made of domestic animals I shall have something further to say under the third head.

2. *Artificial means of destroying the eggs.*—The fact that man can accomplish most in his warfare against locusts by destroying the eggs, has long been recognized by European and Asiatic governments liable to suffer from the insects. The eggs are laid in masses, just beneath the surface of the ground, seldom to a greater depth than an inch; and high, dry ground is preferred for the purpose. Very often the ground is so completely filled with these egg-masses, that not a spoonful of the soil can be turned up without exposing them, and a harrowing, or shallow plowing, will cause the surface to look quite whitish as the masses break up and bleach from exposure to the atmosphere. Great numbers will be destroyed by such harrowing or plowing, as they are not only thereby more liable to the attacks of natural enemies, but they lose vitality through the bleaching and desiccating effects of exposure to the atmosphere. If deeply turned under by the plow, many of them will rot, and the young that chance to hatch will come forth too late the next year to do much harm—providing the same ground be not returned so as to bring the eggs to the surface in the spring. Excess of moisture for a few days is fatal to the eggs, and they may very easily be destroyed where irrigation is practicable. Where stock can be confined and fed on soil filled with such eggs, many of these will be destroyed by the tramping. All these means are obviously insufficient, however, for the reason that the eggs are too often placed where none of them can be employed. In such cases they should be collected and destroyed by the inhabitants, and the State should offer some

inducement in the way of bounty for such collection and destruction. Every bushel of eggs destroyed is equivalent to a hundred acres of corn saved, and when we consider the amount of destitution caused in some of the Western States by the locust invasion of 1874, and that in many sections the ground was known to be filled with eggs; that, in other words, the earth was sown with the seeds of future destruction — it is surprising that the legislatures of those States did not make some effort to avert future injury by offering a liberal price per bushel for the eggs. A few thousand dollars taken out of the State treasury for this purpose would be well spent and be distributed among the very people most in need of assistance.

3. *Destruction of the unfledged Young.*—As I have stated in the articles already alluded to, "heavy rolling, where the surface of the soil is sufficiently firm, destroys the larger portion of them, but is most advantageously employed when the insects are most sluggish. They drive almost as readily as sheep, and may be burned in large quantities by being driven into windrows or piles of burning hay or straw. But the experience of the present year convinces me that by far the most effectual way for man to protect his crops and do battle to these young locust armies — especially where, as in West Missouri, this spring, there was no hay or straw to burn — is by ditching. A ditch two feet wide and two feet deep, with perpendicular sides, offers an effectual barrier to the young insects. They tumble into it and accumulate, and die at the bottom in large quantities. In a few days the stench becomes great and necessitates the covering up of the mass. In order to keep the main ditch open, therefore, it is best to dig pits or deeper side ditches at short intervals, into which the hoppers will accumulate and may be buried. We hear much talk about the powerlessness of man before this mighty locust plague; but I am quite confident that here we have a remedy that is at once thorough and effectual, whereby the people of some of the States, at least, may avert in future such evil as that which befell them this spring. There have been a number of partial attempts at ditching by simply turning a couple of furrows with the plow. Even these will often divert the encroaching insects from their course; but they can never be relied on, and you may rest assured that whenever you hear a man declare that ditching is no protection, he refers to such slovenly, half-made ditches. No instance

has come to my knowledge where a ditch, such as I first described, has failed to effectually keep off the insects. Made around a field about hatching time, no hoppers will get into that field till they acquire wings, and by that time the principal danger is over, and the insects are fast disappearing. If any should hatch within the inclosure, they are easily driven into the ditches dug in different parts of the field.

"There are various other ways of catching and destroying the young locusts, as driving them into converging barriers by means of ropes dragged on the ground, with a person at each end, and then crushing them with shovels or burning them by means of torches made of rags and dipped in coal oil and attached to sticks; catching them with nets, etc.; but nothing equals ditching. As for protecting plants by the application of powders and liquids, I have come to the conclusion that it is out of the question."

If the eggs are duly destroyed, there will be no trouble from the young locusts; but where these once abound, pecuniary inducement to collect and kill them should be offered by the State. It is one of the best means of giving aid and employment to the sufferers, who cannot pursue their ordinary avocation till the plague measurably leaves or is banished.

In this connection, I would also urge the employment of military force, a large amount of which, in times of peace, could be ordered into the field at short notice.

To many, the idea of employing soldiers to assist the agriculturist in battling with this pest may seem amusing and farcical enough; but though the men might not find glory in the fight, the war — unlike most other wars — could only be fraught with good consequences to mankind. In Algeria the custom prevails of sending the soldiers against these insects. While recently in the south of France, I found, to my great satisfaction, that at Arles, Bouche du Rhone, where the unfledged locusts (*Caloptenus Italicus*, a species closely allied to the Rocky Mountain locust) were doing great harm, the soldiers had been sent in force to battle with them, and were then and there waging a vigorous war against the tiny foes. A few regiments, armed with no more deadly weapon than the common spade sent out to the suffering parts of Missouri, Kansas and Nebraska last spring, might, in a few weeks, have entirely routed this pygmean army, and materially assisted the farmer in his ditching operations.

A few other suggestions, and I will dismiss this part of the subject. Hogs and poultry of every description delight to feed on the young hoppers, and will flourish where these abound when nothing else does. It will be well, in the event of a future invasion, for the people in the invaded districts to provide themselves with as large a quantity as possible of this kind of stock. Where no general and systematic efforts were made to destroy either the eggs or the young locusts, and it is found that, as spring opens, these young hatch out in threatening numbers, the intelligent farmer will delay the planting of everything that he cannot protect by ditching, until the very last moment, or till toward the end of June—using his team and time solely in the preparation of his land. In this way he will not only save his seed and the labor of planting, and, perhaps, replanting, but he will materially assist in weakening the devouring armies. Men planted this spring and worked with a will and energy born of necessity, only to see their crops finally taken, their seed gone, and their teams and themselves worn out. The locusts finally devoured every green thing, until, finding nothing more, they began to fall upon each other and to perish. This critical period in their history would have been brought about much earlier if they had not had the cultivated crops to feed upon; and if by concert of action this system of non-planting could at first have been adopted over large areas, the insects would have been much sooner starved out and obliged to congregate in the pastures, prairies and timber. Moreover, the time required for early planting and cultivating, if devoted to destroying the insects after the bulk of them hatch out toward the end of April, would virtually annihilate them. The multiplication of any species of animal beyond the power of the country to support it, inevitably proves the destruction of that species unless it is able to migrate. Let fifty batches of canker-worm eggs hatch out on a single, somewhat isolated, apple tree, and not one worm will survive long enough to mature. The leaves of the tree will all be devoured before the worms are half grown, and the latter must then inevitably perish; whereas, if only a dozen batches of eggs had hatched on that tree, the worms might all have lived and matured. In the same way the young locusts must inevitably perish whenever they are so numerous as to devour every green thing before they become fledged; and under certain circumstances, the sooner such a condition of things is brought about the better.

4. *Destruction of the Winged Insects.*—Man is comparatively powerless before the vast swarms that wing their way from their native breeding places, and this part of the subject may be passed over in this connection.

5 *Prevention.*—What I have so far said, is, perhaps, of more interest to the farmer than to the members of this association; but in dealing with the fifth mode of counteracting the injuries of the Rocky Mountain locust, I appeal more especially to your wisdom and judgment. Prevention in dealing with insect ravages, is always better than cure. "A little fire is quickly trodden out, which, being suffered, rivers cannot quench." The proper way to deal with this insect is to attack it in its native breeding places. It is a fact that does not speak well for some of the countries of the Old World subject to locust injuries, that it is to this day not known whence many of the devastating swarms have their origin. But because European nations have hitherto shown lethargy on this subject, it is no reason why we should. Let us rather in this, as we have in so many things, set an example which they will be glad to follow. In my 7th report I have shown that the insect is not autochthonous in much of the more fertile country it devastates, and that it is never injurious east of the 17th meridian. I have also given reasons for believing that the swarms from which we most suffer originate in the Rocky Mountain regions of Dakota, Wyoming, Montana and British America. Our efforts should be directed to the restriction of the species within its natural limits.

In conclusion, the most important results are likely to flow from a thorough study of the Rocky mountain locust in its native haunts and breeding places. By learning just when and how to strike the insect, so as to prevent its undue multiplication there—whether by some more extensive system of irrigation, based on improved knowledge of the topography and water supply of the country, or by other means of destroying the eggs—we may hope to protect the fertile States to the east from future calamity. This knowledge can never be acquired by any single individual. The subject is of national importance and should receive the consideration of the National Government. If there were no other question in economic entomology to be solved than this one, it seems to me that it would warrant the appeal made by your retiring president, in his paper read before this section, to ask the next

Congress to appoint such a commission as that proposed in the memorial presented for your signatures. It is not merely the question of saving to the nation, in future, such vast sums of money as this insect has filched from the producers of some of the Western States (amounting during the past three years to many millions of dollars); it is a question affecting the welfare of whole commonwealths on the other side of the Mississippi, and the ultimate settlement of a vast tract of country extending from the base of the Rocky Mountains eastward, to which settlement the ravages of the locust in question offer the most serious obstacle.

THE EFFECT OF THE GLACIAL EPOCH UPON THE DISTRIBUTION OF INSECTS IN NORTH AMERICA. By AUG. R. GROTE, of Buffalo, N. Y.

FROM the condition of an hypothesis, the Glacial epoch has been elevated into that of a theory, by the explanations it has afforded to a certain class of geological phenomena. The present paper endeavors to show that certain zoological facts are consistent with the presence in past times of a vast progressive field of ice gradually extending over large portions of the North American Continent and moving from the north to the south. These facts are in the present instance afforded by a study of the Lepidoptera, certain kinds of butterflies and moths now inhabiting the United States and adjacent territories. Before proceeding with the subject, a brief statement of some of the phenomena assumed to have attended the advent of the Glacial Epoch is necessary.

At the close of the Tertiary, the temperature of the earth's surface underwent a gradual change by a continuous loss of heat. The winters gradually became longer, the summers shorter. The tops of granitic mountains in the east and west of the North American continent, now in summer time bare of snow and harboring a scanty flora and fauna, became, summer and winter, covered with congealed deposits. In time the mountain snows consolidated into glacial ice which flowed down the ravines into

the valleys. Meanwhile the northern regions of the continent, which may have inaugurated, submitted extendedly to the same phenomena. Glacial ice, first made on elevations, finally formed at, and poured over lower levels. Glacial streams finally united to form an icy sea whose frozen waters slowly plowed the surface of the rocks; and whose waves, in their movement from north to south, absorbed the local glaciers in their course, and extended over all physical barriers into the Southern States and down the Valley of the Mississippi. To the main Ice-sheet, the Appalachians and Rocky Mountains are supposed to have contributed their local glaciers. Before this frozen deluge the animals must have always retreated. The existing insects of the pliocene must, in submitting to the change of climate which accompanied the advance of the glacier, have quitted their haunts with reluctance, and undergone a severe struggle for existence, no matter how gradually they had been prepared for the encounter. We must expect that multitudes of specific forms ultimately perished of whose remains no traces have been preserved.

Such being a brief statement of the outlines of the opening of the Glacial Epoch, we turn to some facts offered by a study of our existing species of butterflies and moths. The tops of the White Mountains and the ranges of mountain elevations in Colorado, offer us particular kinds of these insects living in an isolated manner at the present day and confined to their respective localities. In order to find insects like them we have to explore the plains of Labrador and the northern portion of the North American Continent, in regions offering analogous conditions to those obtaining on the summits of these mountains. The genera *Oeneis* and *Brenthis* among the butterflies, and *Anarta* and *Agrotis* among the moths, are represented by the same or similar species in all of the above mentioned localities. In the case of the White Mountain Butterfly, *Oeneis semidea*, we have a form sustaining itself on a very limited alpine area on the top of Mount Washington.[1] Although there is some doubt that precisely

[1] See Mr. Scudder's article in the "Geology of New Hampshire," 1,342. Mr. Scudder first pointed out the existence of alpine and subalpine faunal belts on Mount Washington, and interestingly remarks "that if the summit of Mt. Washington were somewhat less than two thousand feet higher it would reach the limit of perpetual snow." Consult also, an earlier paper of great value by Dr. A. S. Packard, Jr., on "The Insect Fauna of the Summit of Mount Washington as compared with that of Labrador" (these Proceedings, Vol. XVI, 151). Dr. Packard, in comparing the climate of the two localities, says: "The seasons correspond very exactly, as the snow melts in the early summer, and ice is formed early in the autumn at about the same dates."

the same form has been discovered in Colorado, the fact remains that butterflies exceedingly like it, though registered by us under different specific names, live in Labrador and Colorado.

Whether the White Mountain Butterfly be, as suspected by Lederer, a local modification of some one of the Labradorian forms or not, the geographical distribution which its genus enjoys cannot be meaningless. The question comes up, with regard to the White Mountain Butterfly, as to the manner in which this species of *Oeneis* attained its present restricted geographical area. How did the White Mountain Butterfly get up the White Mountains? And it is this question that I am disposed to answer by the action attendant on the decline of the Glacial Epoch.

I have before briefly outlined the phenomena attendant on the advance of the Ice-sheet, and I now dwell for a moment on those which must equally be presumed to have accompanied its retirement. Many of the features of its advance were repeated in reverse order on the subsidence of the main Ice-sheet or Glacial sea. The local glaciers appeared again separate from the main body and filled the valleys and mountains and ravines, running thus at variance with the main body of the Glacier, being determined by local topography. A reversal of the temperature shortened the winters and lengthened the summers. Ice-loving kinds of insects, such as our White Mountain Butterfly, hung on the outskirts of the main Ice-sheet, where they found their fitting conditions of temperature and food. The main Ice-sheet had pushed them insensibly before it, and, during the continuance of the Glacial Epoch, the geographical distribution of the genus *Oeneis* had been changed from a high northern region to one which may well have included portions of the Southern States. And, on its decline, the Ice-sheet drew them back again after itself by easy stages; yet not all of them. Some of these butterflies strayed by the way, delayed by the physical nature of the country and destined to plant colonies forever separate from their companions. When the main Ice-sheet left the foot of the White Mountains, on its long march back to the pole where it now seems to rest, some of these wayward, flitting, *Oeneis* butterflies were left behind. These had strayed up behind the *local* glaciers on Mount Washington, and so became separate from the main body of their companions which journeyed northward, following the retirement of the main Ice-sheet. They found in elevation their

congenial food and climate, and they have followed these gradually to the top of the mountain, which they have now attained and from which they cannot now retreat. Far off in Labrador, the descendants of their ancestral companions fly over wide stretches of country, while they appear to be in prison on the top of a mountain.

I conceive that in this way the mountains generally may have secured their Alpine animals. The Glacial Epoch cannot be said to have expired. It exists even now for high levels above the sea while the Laplander and Esquimaux find it yet enduring in the far North. Our yearly winters are fractions of the Glacial year. Had other conditions been favorable, we might now find Arctic man living on snow-capped mountains in the Temperate zones.

At a height of between 5,600 and 6,200 feet above the sea and at a mean temperature of about forty-eight degrees during a short summer, the White Mountain Butterflies (*Oeneis semidea*), yet enjoy a climate like that of Labrador within the geographical limits of New Hampshire. And in the cases of the moths[2] an analogous state of things exists. The species *Anarta melanopa* is found on Mount Washington, the Rocky Mountains and Labrador. *Agrotis islandica* is found in Iceland, Labrador, the White Mountains, and, perhaps, Colorado.[3] As on islands in the air, these insects have been left by the retiring of the ice-flood during the opening of the Quaternary.

On inferior elevations, as on Mount Katahdin in Maine, where we now find no *Oeneis* butterflies, these may have formerly existed, succumbing at last to a climate gradually increasing in warmth from which they had no escape; *while the original colonization in the several instances must have always greatly depended upon local topography.*

In conclusion, I have briefly endeavored to show that the present distribution of certain North American insects may have been brought about by the phenomena attendant on the Glacial Epoch. The discussion of matters connected with this theoretic period of the earth's history, still, as it now appears, brings out more and more a clearer conception of its actuality. I hope that

[2] I have since (*Psyche*, I, 131) recorded the first indication of the occurrence of the Arctic *Laria Rossii* on Mount Washington, from a single specimen taken by Mr. B. Pickman Mann, above the tree line.

[3] I believe Dr. Packard's identification of this species, in Prof. Hayden's Reports, is incorrect. The Coloradian species is *Agrotis auxiliaris*, Grote.

my present statements may draw the attention of our zoölogists more fully to the matter, seeing that we have in our own country fields for its full exploration. And I permit myself to believe, that testimony as to the former existence of a long and widely spread winter of the years, is offered in evidence through the frail, brown, *Oeneis* butterflies, that live on the tops of the mountains.

ARE POTATO–BUGS POISONOUS? By AUG. R. GROTE AND ADOLPH KAYSER, of Buffalo, N. Y.

A STATEMENT of the poisoning qualities of the *Doryphora decemlineata* or Potato-bug has repeatedly been made in public prints, and notably in the Seventh Report on the Insects of Missouri, by Professor C. V. Riley. It is claimed that by coming in contact with the bugs or inhaling the steam or smoke produced by boiling or burning them, persons have exhibited various symptoms of cutaneous or nervous disease.

To investigate the matter, a quantity of the bugs, collected from fields near Buffalo where no arsenic had been used, was submitted to distillation with salt water so as to allow of an increased temperature. Under this process about four ounces of *liquid* was procured from one quart measure of the insects. This *liquid* was perfectly clear and emitted a highly offensive smell; it proved of alkaline reaction on account of the presence of a certain quantity of free ammonia and carbonate of ammonia.

Again, an equal quantity of the bugs was used to prepare a *tincture* made as follows: Absolute and chemically pure alcohol was condensed upon the live bugs; after a digestion of twenty-four hours the alcohol was evaporated at a gentle heat. The tincture so obtained had a decidedly acid reaction, was brown in color and not disagreeable in smell.

To ascertain the effect on the animal system of the *liquid* and the *tincture* above described, a number of frogs were procured for the experiment. About one-half cubic centimeter of the *liquid* and the *tincture* was introduced, separately, into the stomach.

Neither the *liquid* nor the *tincture* produced any apparent effects. The vivacity of the frogs so treated continued unimpaired, notwithstanding the complete retention of the doses.

Again, two fresh frogs were submitted to a hypodermic injection in the hind legs of the *liquid* and the *tincture*, by means of an ordinary hypodermic syringe. The injection of the distilled *liquid* was unattended by injurious results. A slight disinclination at first to use the hind limbs was shown also in the case of another frog which was treated hypodermically with pure water, to check the results obtained.

The injection of the *tincture*, however, proved fatal to the patient. A few moments after the injection the leg operated upon seemed to become paralyzed and the heart stopped beating within thirty minutes afterward, by which time the other two frogs hypodermically treated seemed to have completely overcome the effects of the operation.

The *tincture*, although highly concentrated, contained but a small quantity of animal acids which, when saturated with bases of potassa and soda, formed hexagonal deliquescent crystals visible under the microscope, but insufficient in quantity to analyze. It is known that such acids are very active in their effects upon the animal system. The bite of a flea or of a bed-bug is attended by an introduction of acids which produce a swelling by the coagulation of the albuminous fluids of the body. The rapid coagulation of milk was shown by the experiment of introducing a few drops of the *tincture*, above described, during the present experiments. In the case of the insects above mentioned, especial organs are occupied with the secretion of the acids which serve the insect economy by coagulating those parts of the blood of the victim which may not be useful for food. No such organs have been noticed in the Potato-bug. The presence of the acid leads us to conjecture as to the origin of such organs, while they have apparently not become developed in the Potato-bug. The acids being found to be present in such small quantity the conclusion is unavoidable that the bugs are *not* poisonous in the light of the present experiments.

Rather does it seem likely that the published statements to the contrary were based on erroneous observations, while it is extremely probable that certain of the more aggravated and circumstantially detailed cases of poisoning are due to the effects

of arsenic (Paris green and arsenious acid) which is now profusely used for the extermination of the bugs. Many metallic salts will produce cutaneous irritation; when sublimed by heat the inhaled fumes of arsenic will produce nervous disorder; the effects of the Paris green may have been mistaken for those of the Potato-bugs.

It is credible, moreover, that, when larger amounts of the bugs are thrown into a fire to destroy them, even when not containing any arsenic, an incomplete combustion might take place, in which case carbonous oxide (C O) would be produced, which would certainly cause the evil effects complained of. It may also be remarked that previous to the advent of the Potato-bug, the potato-plant itself has not been so freely handled as lately; an enquiry as to the effects of the entrance of the minute hairs from the leaf into the skin and into the properties of the juice of the plant, might show cause for some symptoms complained of.

At this time when the use of arsenious acid is forbidden in Germany in the manufacture of aniline colors, on account of its evil effects on living organisms, it may not be thought improper to call the attention of the people of our country to the present use of arsenic in the culture of so universal a food plant as the potato.

A Method of Bleaching Wings of Lepidoptera to facilitate the Study of their Venation. By George Dimmock, of Cambridge, Mass.

In the common method of destroying the scales on the wings of Lepidoptera, for the purpose of studying their venation, by means of caustic alkaline solutions, there is danger of not arresting the action at the proper moment and consequently of destroying not only the portions which it is desirable to remove but also the scale-supporting membrane and even the delicate veins themselves. An application of a modification of the chlorine bleaching process, commonly used in cotton bleacheries, obviates the necessity of removing the scales and leaves the wing perfect.

There are many ways in which this kind of bleaching can be done, but I have found that the most convenient method of applying the chlorine is as follows. The wings must first be soaked a few moments in pure alcohol in order to dissolve out the oily matter in them. If this is not done the surface of the wings acts as a repellent, and will not be moistened by an aqueous solution. When the wings have become thoroughly soaked by the alcohol they are ready to be removed to a solution of common bleaching powder. This bleaching powder is sold by druggists as "chloride of lime," but it is really a mixture of calcic hypochlorite, calcic chloride, and calcic hydrate. Ten parts of water dissolve the first two compounds, leaving nearly all the third suspended in the solution. The solution should be made with cold water, filtered, and kept in a tightly corked bottle until required for use. When the wings are transferred to this solution the bleaching commences and in an hour or two the wings are devoid of markings, although the veins retain a light brown color. This is due to the fact that chlorine cannot quite decolorize animal matter, or any substance containing nitrogen, as it does vegetable tissue.

The most probable theory of the action of this bleaching mixture is that the chlorine set free from the solution unites with the hydrogen of some of the water, forming hydrochloric acid and setting free the oxygen of the water to oxidize the coloring matter in the tissues. This oxidation forms new and colorless compounds which are perhaps soluble and thus are entirely removed.

But to resume the process. After the color has sufficiently disappeared from the wings they should be transferred to a wash composed of one part of strong hydrochloric acid to ten parts of water. And here it may be added that in case the bleaching does not readily commence upon immersion in the bleaching solution, the action may be hastened by a previous dipping in the dilute hydrochloric acid. In the bleaching solution a crust of calcic carbonate, formed by the union of the calcic hydrate of the solution and the carbonic dioxide of the air, is deposited on the wings, and this calcic carbonate the final wash in dilute acid will remove. As soon as the calcic carbonate has disappeared, and all bubbling, consequent upon its decomposition by the hydrochloric acid, has ceased, the wings should be well soaked in pure water. They

may then be secured on cards with a mucilage of gum tragacanth; or upon glass by the proper transfers, through alcohol and chloroform, to Canada balsam.

A solution of sodic hypochlorite, known as *Eau de Labarraque*, or a solution of potassic hypochlorite, known as *Eau de Javelle*, when used in place of the solution of bleaching powder do not leave a deposit of calcic carbonate on the wings and thus dispense with the wash of dilute acid. A solution of zinc hypochlorite acts more delicately than a solution of sodic hypochlorite, and may be used in place of the latter, as may also solutions of aluminic hypochlorite, or magnesic hypochlorite.

These bleaching processes preserve the most delicate wings unbroken, and where the specimens are of rare species, "rubbed" wings can be used, the absence of the scales not being evident after bleaching. The costal venation of the wings of Hesperidæ can be clearly determined in bleached wings.

Provided the wings are not kept too long in the bleaching solution or in the dilute acid, the scales remain perfect and in position, although rendered so transparent that their presence is scarcely noticeable, even with a lens. That they still remain is easily proved by examining the torn edge of a piece of wing under a compound microscope, when the transparent scales will be seen overhanging the edge like shingles upon a broken roof.

DEMONSTRATION OF LOCOMOTION IN THE LARVÆ OF THE ŒSTRIDÆ. By CHARLES. H. ALLEN, of Chicago, Illinois.

(Communicated by O. S. WESTCOTT.[1])

MARCH 28, 1872, I was called to visit a boy 10 years of age; I found, that for several weeks he had a very poor appetite, had been very feeble, had lost flesh, had restless nights and had complained bitterly of suffering from sensations of pricking, crawling

[1] On account of Dr. Allen's illness this paper was epitomized and read by Mr. Westcott, of Chicago.

and biting; all which had increased in severity during the previous ten days. At first, these sensations were observed in the left hypochondrium, but subsequently from point to point, until they became unusually marked in the right hypochondrium and thence they extended up the right front chest.

On stripping the boy, my attention was directed to a yellowish line, extending from the left to the right side of the front body, precisely where the boy affirmed that he had the aforesaid sensations. I observed also a much less distinct line extending up the right front chest, until it reached the right submaxillary gland, over which the cellular tissue was puffed, but not indurated. Just above and directly behind the right ear I observed a swelling, equal in size and similar in form to two medium sized peas, placed side by side. The boy assured me, that during the previous day and night, he had at this point, behind his right ear, exactly the same sensations that he had previously had in the front body and up the right side. He affirmed also, that these sensations were always more severe by night than by day, that he was compelled to rub and scratch the skin, under which these peculiar feelings existed, and yet the rubbing and scratching gave him no relief, but rather increased his sufferings and gradually transferred them to other points, and that the aforesaid sensations of pricking and crawling and biting never returned to their former localities. On pressing the swelling behind the right ear, I thought I perceived very slight motion. An incision was made through the derma at a point directly over the tumor. A light yellow serum oozed out, and on making lateral pressure, larva number one presented itself. Two days afterwards, the patient complained of having the same feelings at a point directly over the spine and an inch or two below the scapulæ. On examining this spot I found a tumor exactly like the first. I saw no discoloration, but did see an almost invisible lucid point on the top of the swelling. On cutting through the derma, the same yellowish fluid appeared, and on making lateral pressure, larva number two appeared. The boy assured me that he had not scratched this locality much because he could not get at it.

A day or two subsequently, the child had similar sensations on the top of his head. I marked the spot, where I could very indistinctly feel a tumor. I clipped the hair and marked with nitrate of silver the exact position and direction of this swelling. The

next day I found that it had moved an inch, I then cut through the derma, when the aforesaid yellowish fluid oozed out, and larva number three appeared.

A few more days passed away, when the boy complained of unusual sufferings from the aforesaid sensations in his left wrist; and there, sure enough, I found a fourth swelling. The larva could be felt more distinctly than could any one of the others. The exact spot in which it was situated was very distinctly marked by nitrate of silver. For the benefit of science, I persuaded the boy to let the creature remain where it was until the next day. At an early hour the next morning, I was summoned to visit the patient and was informed that he had a very bad night, had suffered very much more than on any previous night.

On inspecting the spot so well marked by nitrate of silver, I could not find the swelling, or the larva, whose position had been so definitely indicated. I observed that the surface about the left elbow had a dark and yellowish tinge, that the cellular tissue was very much swollen and indurated, and that the entire elbow appeared as if it had been badly bruised. As the larva, the presumed cause of all this trouble and suffering, could not be felt, and as the patient still had the very same feelings he had experienced in his left wrist, it was deemed best to make an incision through the derma at the elbow, at the point where these sensations were perceived. I requested J. M. Keniston, M. D., to do this with care, so that should the larva be at the point indicated by the sensations of the sufferer, it would not be injured, whereupon, as previously, yellowish serum oozed out and larva number four appeared.

Two of these larvæ I presented to Dr. Hagen of Harvard University, who, after a careful examination, says, "I think these larvæ belong to the order Diptera, and to the family Œstridæ, or Botflies. They are in the first larval state—a state, identified in a few species only, especially of those purely American—a specific determination would be therefore nearly impossible.

Dr. F. Brauer of Vienna, in his monograph of the Œstridæ, published at Vienna in 1863, describes and figures the first larval state of an European species, *Hypoderma Diana*, and his descriptions and figures agree so well for the parts of the mouth and anus, that these larvæ, though belonging to a different species, yet undoubtedly belong to some of the genera which live under

the skin of living animals. The reasons, we think, for believing these larvæ to be in their first stage, are as follows: First, it has horny hooks, as these genera are undergoing a retrograde metamorphosis in the next stage, losing the horny hooks no longer necessary for their mode of existence. Secondly, that this is in its first stage of existence is shown by nearly entire lack of spines, or tubercles, so characteristic of the later stages of its larva state. As the larva remains the longest time in its first stage of larva life — seven to eight months, it is very proper that the spines and tubercules should be developed at a later period, since the larva thus gives less irritation to its host and can thus grow better and without harm to animals or larva. And for a still stronger reason, thirdly, these larvæ are shown to be in the first stage of larval life by their having respiratory scaly plates on the posterior end of the abdomen, thus agreeing very well in this regard with Brauer's figures. But I see a cluster of fine branchiæ adapted to the skin, not mentioned by any naturalist. Perhaps these also belong to the first stage only, especially as the first state of the genus to which this larva belongs is still unknown. This question settled, that it is a larva belonging to the Œstridæ, we seek for its species, or, at least, for its genus.

There exists no special work on the North American Œstridæ. The genera Hypoderma and Dermatolis are not yet known as coming from America, but it is very probable that *Hypoderma* lives in the United States."

Dr. Hagen felt so great an interest in the larvæ, which I sent him, that he sent the other two to Dr. Brauer of Vienna, who, Oct. 16, 1872, reported, "these larvæ agree so well — so exactly with the description and figures given by me for the larvæ of the genus Hypoderma — especially for the species *Hypoderma Diana* and *Hypoderma bovis*, that I have no doubt, that these larvæ do belong to Hypoderma, and are in the first stage of larval life, and the chitinous plates on the anal region are just as I described them. It is impossible to determine the species of a larva in its first stage of larval life, but surely, no difference exists between the *Hypoderma Diana* and the larvæ from this child. It would aid in determining the species, if we knew among what animals this child had been."

Here let me say, that my patient spent the summer of 1871, at Charlottetown, Prince Edwards Island.

Before receiving Dr. Brauer's report, I had directed a note to Richard Johnson, M.D., a practitioner of high repute on that Island, describing my case somewhat minutely, and asking, whether, or not, a case similar to this had occurred on that island. He promptly replied, "that he had not seen a case answering my description, but a case was reported several years ago, as possessing similar traits. A second case was reported as having occurred six years ago, but was not witnessed by any medical gentleman. The facts as given me, were, that a young man of 20 years of age had suffered from what is termed warbles, or wurmals, a term designating the swellings on the back of the ox produced by the oxfly, or *Œstrus bovis.* Thus I think no doubt remains about the origin of the four larvæ, taken from the cellular tissue of my patient. The time of the exposure of his naked body to the mother fly whilst bathing almost daily in the pond of a pasture, in which were a large number of cattle, and the time, when the bots in his cellular membrane appeared, all correspond.

The larvæ of Œstridæ are divided into three groups, the *gastriculæ*, which live in the stomach, the *caviculæ*, which live in the nose or other cavities, the *subcuticulæ*, which live in the cellular tissue. The question of some interest to entomologists is, do the larvæ of the Œstridæ possess locomotive powers?

The mother fly of the *gastriculæ* deposits its eggs on the horse for instance; the horse experiences some uneasiness from their pressure, tries to wipe them away with its mouth, or tongue, and thus moistens them with warm saliva; some adhere to its tongue, hatch at once and instinctively crawl down the gullet into the stomach, their proper feeding ground, fasten themselves by two hooks to the inner coating of the stomach, and arrange themselves in rows as regularly as many insects deposit their eggs, and, retaining their grasp until mature as larva, then let go or pass with the fæces to the ground, penetrate it and there become pupæ.

Again, the mother fly of the *caviculæ*, as the *Œstrus ovis*, deposits her eggs on the lower edge of the nasal cavity of the sheep. These eggs absorb moisture, and, hatching at once, crawl up into the upper part of the nasal cavities or in other open cavities, and even into the brain, attach themselves by mouth-hooks to the mucous membrane, or inner lining of these cavities, and remain until mature as larvæ; then fall to the ground, penetrate it and

there undergo their last change. Thus we see, that the *caviculæ* have locomotive powers.[2]

But do the *subcuticulæ* move? Entomologists may say no. Dr. Brauer of Vienna says, they penetrate the skin, and go even deeper, *when disturbed.* How much deeper? The four larvæ taken from the cellular tissue of the patient were disturbed by his excessive scratching and rubbing, especially number one and number four, but they did not penetrate any deeper and yet they showed to a demonstration, that they did move through the cellular tissue; number one, at least thirty inches and number four at least six inches.

Dr. Hagen, endorsed by Dr. Brauer, affirms, that these larvæ were of the family Œstridæ, group *subcuticulæ*, genus *Hypoderma*, in the first stage of larval life. No doubt, the normal habit of the larva of the *Œstrus* (*Hypoderma*) *bovis*, is to remain in its nidus in which its mother placed its germ. In this case, the mother made a mistake in depositing her eggs, as does the dung fly in depositing its eggs upon certain rank smelling plants instead of upon decaying flesh, showing that instinct is not unerring.

My observation, then, is that the larva of the botfly, *Hypoderma bovis*, can move through the cellular tissue; that my patient's rubbing and scratching compelled larva number one to move from the left side to the right side of the boy's body, thence up to the cellular tissue over the submaxillary gland and thence to the space directly behind the right ear. Larva number four moved from the wrist to the elbow.

Remembering, that the *subcuticulæ*, at maturity, do wriggle out of their nidus or native home, and penetrate the ground, that three of the four larvæ did move, and that the one on the back, which was the only larva that did not move, had over it through the derma, a nearly invisible lucid spot, which the other three ought to have had; that this one could not be reached by the boy, though he had the self-same sensations in it that he had in the other larval localities, we cannot escape the inference, that the larvæ of the *Hypoderma bovis* when disturbed, as three of these were, may leave their homes and wander very far through the cellular tissue.

I may add, that after these larvæ had once commenced locomo-

[2] It is claimed by some modern investigators that some if not all of the *caviculæ* are even viviparous.—O. S. W.

tion, they may have naturally become restless from want of air, since their respiratory apparatus is situated in the hind part of the body, and the lucid spot on the top of the swelling is evidently the channel through which air may enter the respiratory organs.

On the Primary Divisions of the Chitonidæ. By Philip P. Carpenter, of Montreal, Canada.

A large proportion of existing Conchologists and Palæontologists still regard the Chitons not only as a mere family of Prosobranch Gasteropods, closely allied to the limpets, but also as consisting but of one genus, with the exception, perhaps, of Chitonellus. They are, however, a unique and very ancient type of animals, presenting in the main a Gasteropodous Molluscan form, but uniting to this many special characters of the Articulates.

I have lately had an opportunity, through the kindness of Count Pourtalès, of examining probably the largest collection in existence of alcoholic specimens. This confirms my previous impression that there is unusually little difference in the animals of the whole group; while the external forms vary greatly. Even if we compare the covered *Cryptochiton*, the exposed *Chiton;* the worm-like *Chitonellus*, the broad *Radsia;* the *Mopaliœ* advanced in front, and the *Schizochitons* clipped behind; the inside view of the animals presents no ordinal divisions, and extreme forms are gradually connected by intervening links.

It is natural, therefore, that the few naturalists who have classified the group should have availed themselves of superficial characters. But as these appear, not coördinately, but in various permutations and combinations, it is difficult to choose primary characters which do not interrupt the natural sequence of others. Gray and Adams make their primary divisions into the Pore-bearing and Non-pore-bearing groups; while Middendorff, who worked more at their anatomy probably than any other naturalist, made this simply the lowest division of the sub-subsections of his sub-genera.

It seems to me that the most reliable characters are found in the articulation of the shelly valves; the forms of which correspond, in relative importance, to the changes of hinge-articulation in bivalves, and columellar marks in univalve shells. It is a strange peculiarity of Chitons that the heads in the whole group are nearly alike, and that they show their differentiation at the tails. We get, therefore, a *primary division* between I, the *Regular Chitons*, in which the Head and Tail Plates are similarly articulated; and II, the *Irregular Chitons* in which the Tail Plate goes through various modifications. In each of these groups we have the same girdle-changes repeated; the valves being more or less exposed, and the outer skin being bare, hairy or scaly, with or without regular pores.

Among known recent Chitons, there is a very small group of small shells, in which the characters fade away by the entire absence of insertion-plates round the sides. These might naturally be considered as ordinary chitons, degraded. But on examining the series of Palæozoic Chitons in the British Museum, and (representing a larger number of species) in that of Cambridge, U. S., I find that *all of them* present the same negative characters. The same is true of the Canadian Silurian form, *Priscochiton*. And yet, among these ancient forms, there are species rivalling in size the larger of the living groups, and presenting similar variations in the tail plate to those now existing. *As far, therefore, as our present materials enable us to judge*, there are two fundamental types of Chitons, the *Perfect* and the *Imperfect*, corresponding to the Placental and Implacental Mammalia. In each of these are found the Regular and the Irregular forms previously noticed; and in each may have existed the same changes of girdle characters. The Imperfect Chitons began the series; culminated in the Carboniferious period, in which both Regular and Irregular forms were most developed; and retain their existence now only in a few small genera; while the Perfect Chitons began in the Neozoic eras, and culminate at the present day.

If any Members of the Association have specimens, either recent or fossil, which they are willing to lend me for examination, I should be particularly pleased to study them without delay; as the Smithsonian Institution will shortly resume the printing of my monograph of the group. They can be sent by post to me, at 508 Guy St., Montreal, Canada.

EMBRYOLOGY OF THE FRESH-WATER MUSSELS. By WILLIAM K. BROOKS, of Cleveland, Ohio.

THE following is an account of some of the more interesting results reached by a careful study of the embryology of the Naiades.

Segmentation begins by the appearance of a direction-cell, and the first cleavage plane originates at the point thus marked.

After segmentation the mulberry mass forms a "gastrula" by invagination. On account of the opacity of the yolk and its small size it was difficult to observe the internal structure of the gastrula with perfect satisfaction, but appearances seemed to indicate that the outer and inner layers were in contact, thus obliterating the cavity of segmentation.

The opening of the gastrula soon became closed by the apposition of its margins, and no traces of it could be found in eggs a little more advanced.

The embryo now becomes slightly lengthened; the anterior end is indicated by the presence of a simple band of cilia — the rudimentary velum — and five or six bunches of setæ are seen arranged somewhat symmetrically in pairs along opposite sides of the now very worm-like embryo.

During development the ends of the velum lengthen, bend towards each other and at last unite, forming the closed, lobed circlet of cilia so characteristic of the embryonic mollusca.

The shell is formed by the *conversion* of a layer of epithelial cells upon the dorsal surface of the embryo into a horny cap or hood, in or on which the earthy matter is deposited in amorphous granules.

This hood is, at first, very similar to the embryonic shell of a gasteropod, and is drawn down into the sides of the body by the action of the developing adductor muscle, and soon splits along the back, thus forming the two valves of the lamellibranchiate shell.

According to these observations the two valves of a lamellibranch are together the homologue of the gasteropod shell, which, in the adult, conforms much more closely to the embryonic type than does the shell of an adult lamellibranch. As Dentalium is recognized as a form uniting the lamellibranchs to the gasteropod stem, it is interesting to observe that the growth of the shell in the embryo of Dentalium also presents a transition between the

method observed in the mussel and that known among gasteropods. According to the observations of Lacaze-Duthiers the shell of Dentalium is, at first, as in the gasteropod and lamellibranch, a hood or cap upon the dorsal surface of the embryo, and bends down into the sides of the body in the manner already described in the fresh-water mussel, but does not divide along the back, as in the mussel, and finally becomes united along its lower edges so as to form a tube.

The changes already described take place quite rapidly, but after the formation of the shell development goes on very slowly and irregularly, and the interbranchial life of *Anodonta implicata* extends over a period of about seven months. At the end of this time the animal is furnished with a four-lobed velum; the byssus-filament; adductor muscle; the retractor muscles of the region of the velum, and marginal mantle-muscles. The most anterior pair of setæ, just behind the velum, become modified into the otocysts.

The valves of the shell are armed with the hooks and hooklets, so often described, which are joined to the shell by hinge-ligaments; are retracted by special muscles, and serve to lock the two valves together in the manner figured and described by Quatrefages.

After the lapse of a somewhat variable period — about twenty-six weeks — the young, 700,000 or more in number, are discharged from the body of the parent. They are true larvæ, differing greatly in form and structure from the adult; possessing organs of which no traces remain at a later stage, and lacking such systems as the circulatory, branchial and digestive. The digestive and circulatory organs mentioned and figured by Quatrefages are the lobes of the velum and the coiled organ which forms the byssus; and the branchial and cloacal openings noticed by Carus are, without doubt, the larger lobes of the velum.

In the present unsatisfactory state of our knowledge of the development of the marine lamellibranchs, it is not very safe to generalize; but we may state with confidence, I think, that the Naiades, like many other fresh-water animals, differ greatly from their marine allies in the method of development, and pass through a true larval stage at present unknown among marine forms.

So many embryonic forms, throughout the animal kingdom, have been so satisfactorily interpreted according to the theory of evolu-

tion, that we frequently meet the statement, made by very high authorities, that as we trace an animal back from the mature form to the egg the special modifications of the different organs disappear, in the individual, inversely in the order in which they were acquired by the race; so that in earlier and earlier stages we find structures which are shared by a greater and greater number of species, and accordingly may infer descent from embryology.

This may be pretty nearly true where all the animals of the group compared are exposed to about the same conditions during growth, but it is possible to distinguish an embryo Anodonta from an embryo Unio, and the embryos of at least some species of Unios from each other, at a stage so early that they lack many characteristics common to all adult mollusks, and while they are still enclosed in the egg, and carried in the gills of the parent, and exposed to what would seem to be perfectly similar conditions. Wherever they are exposed to dissimilar conditions during development we ought reasonably to expect the embryos of even closely related species to acquire, at any stage where they are needed, special modifications to meet varying conditions. We can infer descent from embryology, then, only in those cases where the complete history of a sufficient number of forms has been traced to enable us to separate what is shared by all from what has been acquired for a special purpose. In the case of Anodonta and Unio the gastrula and veliger stages undoubtedly show relationship, since they have been traced in so many of the invertebrates; but, on the other hand, I think it will in time be shown that the larva or "glochidium" is a specially modified stage, adapted to a special purpose, and has no bearing upon the question of the origin of the group.

PROTOZOAN STUDIES. By W. S. BARNARD, of Canton, Illinois.

(ABSTRACT.)

IN studying American Protozoa, representatives of most European genera are found, and it is seldom indeed that even a new species is discovered. This wonderfully broad distribution is probably due to their being so exceedingly small that they may

be carried from place to place with the minute particles of water in the air, or in the moisture on the surface of wading, natatorial and aquatic animals, as well as from the fact that the numerous germs and even the adult forms of many are capable of being dried up and wafted, like particles of dust, upon the winds from one part of the earth to another, and wherever they may chance to fall into the water under favorable conditions may revive, live and multiply.

A very remarkable rhizopod-genus, one of the most curious known, is

Echinopyxis Clap. et Lachm. (Centropyxis Stein).

Claparède and Lachmann characterize it as having "a shell furnished not only with a round opening giving passage to locomotor pseudopods, but also with tubular prolongations open at their extremity. Through each of these prolongations can pass out a slender pseudopod, which does not seem to be of any value for locomotion." They describe the only species known as

E. aculeata (Syn. Arcella aculeata Ehr., Difflugia aculeata Perty). "*Diagnosis.* Shell oblong, opening eccentric, like the mouth of a Spatangus." This genus and species a few years since described in Europe also exists in America, where I have observed it several times. Externally the shell seems to consist entirely of agglutinated sand grains and bears several (4–6) tubules near its larger end. These minute tubes have the shape of horns, but by strong magnifying power are seen to be open at (what with lower power seems to be) their points, from which very slender pseudopods are occasionally projected. Their substance appears like *diatomin*, and is an outward continuation of an inner lining, upon which the sand grains are incrusted, as may be best observed on the margins of broken shells. The question arises, for what purpose are these small, spiny tubes? They probably serve as spines or bayonets for weapons of defence, as do the diatom shells I have observed fixed erect on another rhizopod's shell, probably belonging to *Difflugia bacillariarum* Perty, but they probably also serve some other purpose not now understood. Beside this I have studied in this country several specimens representing two well marked new species as follows:

Echinopyxis tentorium, nov. spec. The test conical with a concave base and bearing one tubule on its apex; opening subcentral.

Its only decidedly specific characters belong to the shell, which presents the general form of a tent, or inverted funnel, and is so opaque that nothing can be seen of the amœboid animal within, except its pseudopods, which are sometimes, though seldom, extended from beneath, serving especially for locomotion and prehension. Also, a delicate plasmic point is occasionally projected from the single tube above. Specimens of this are found on the muddy and sandy bottoms of creeks and ponds in New York.

Echinopyxis hemispherica, nov. spec. Test hemispherical, depressed; tubules several (3–7), more or less elongated and crooked, with large distal openings; the main aperture subcentral. This form occurs also on the muddy and sandy bottoms of ponds and creeks in New York. The irregular or variable number of tubules is probably due to the fact that sometimes one or more becomes accidently broken off.

If we admire the instincts of birds and bees, and wonder that such low animals as tubiculous worms can construct for their protection encasements of united particles of sand, how much more marvellous is it that we find organisms so low as the amœba, almost structureless masses of living protoplasm, endowed with this wonderful inherited habit of constructing artificial houses for themselves!

Euglypha tegulifera, nov. spec. This is a very beautiful little rhizopod and is characterized by a quite peculiar and interesting shell. It occurs among fresh-water algæ, as I have seen it in New York, with an ovoid test, glistening in strong light from the effect of a layer of crystalline blocks of unequal height, which pave the external surface. The inner homogeneous capsule upon which the pavement lies is quite thick, exhibiting the color of diatomin and forming a smooth (not dentate) margin about the pseudopodal orifice. Protected within this hard, rough case, lies the delicate, granular, plasmic amœboid body, which does not entirely fill the shell, but presents a large nucleus and several small vacuoles, at times extending itself outwards by long, usually branching, sometimes anastamosing, pseudopods.

To these were added descriptions of some new infusorian and rotatorian species.

ARE INSECTS ANY MATERIAL AID TO PLANTS IN FERTILIZATION? By THOMAS MEEHAN, of Germantown, Penn.

THOSE of us who are growing gray remember, when our Botany was young, the pleasure it gave us to note the floral arrangements we thought so perfect for insuring self fertilization. For instance we would take a Fuchsia, and note its pendulous flowers, and that the anthers were so placed that the pollen must fall on the stigma. But modern science checks this young exuberance. The pollen of the Fuchsia is gelatinous and does not fall, and what can we say? Yet if we had looked deeper, we might have noted that allied genera as Gaura, Epilobium, Œnothera, and even some Fuchsias had their sexual organs of the same relative positions, and yet with their stamens erect. But it seems to be the misfortune of popular science that it fails to see facts, except as they seem to favor some popular theory which it becomes fashionable to adopt. It is the object of this paper to show that we are in danger of a similar prejudice in favor of the theory of insect fertilization.

At our last meeting in reply to a question by Professor Cox as to why Apocynum caught insects, no better thought could occur to Professor Asa Gray than the playful remark that it was simply an illustration that even here evil had found an entrance to the world. But while Professor Gray was cautiously feeling his way here, Dr. Hooker on the other side was more venturesome. He was asking us to imagine a time when plants accidentally permitted the accumulation of insects in some parts of their structure, and the practice became developed because found useful; and he would probably have said that Apocynum was simply experimenting as to what use it could make of the insects it had caught. This reference illustrates the tendency of thought in regard to insect fertilization. Müller and others teach that plants came in time to abhor in-and-in breeding, to desire cross fertilization; and, excluding a few cleistogamous forms and some which employed the winds, took on themselves color and sweet odors, as if directed by a sort of foreknowledge that in this way they could entrap insects into their service. Müller indeed contends that some plants came in time to be very choice in the selection of lovers, and contracted their pistils, and extended their corollas, so that only a certain class of insects could enjoy their favors. I have, I know, placed the plant as an actor, more strongly than the distinguished

gentlemen would who are working in this field. They take the progression in a more passive light. I am referring to popular apprehension — and after all this is but a metaphysical distinction of little moment here.

In any interpretation of this kind, it greatly changes our views of nature. It is not for us to say they are not correct, but we have a right to insist that the facts shall be subject to every test that sound reason may suggest.

I have thought it best to take as my text the exact words of a popular teacher of science. He says:—"All plants with conspicuously colored flowers, or powerful odors, or honeyed secretions, are fertilized by insects; all with inconspicuous flowers, and especially such as have pendulous anthers, or incoherent pollen, are fertilized by the wind. Therefore before honey feeding insects existed the vegetation of our globe could not have been ornamented with bright colored flowers." This view is the general one, and thus has arisen a classification to which all flowering plants are referred. They are either *Anemophilous*, wind lovers, or *Entomophilous*, those which desire insect aid.

I may here remark that a sort of necessity for cross-fertilization was perhaps suggested by a belief in a popular impression that is probably erroneous. We thought nature had a horror of in-and-in breeding. Our selected breeds of cattle are the results of this sort of selection; and they have proved just as healthy and productive as the veriest scrub. But it was thought they would at least revert to their originals when the hand of man was taken away. But at our last meeting Professor Brewer showed this was also a mistake. Quite recently Mr. George Darwin has shown, in a remarkable paper made up of an extensive study of the old families among the English nobility, where intermarriages among relatives have been a sort of social necessity for ages, that the popular idea is erroneous. These intermarriages have resulted as productively and as healthily, mentally and morally, as the average marriages of the rest of the world. The question of insect fertilization is, therefore, no longer a question of necessity; it has to stand on the facts alone as they are adduced.

That some plants require external aid is certain. Yucca and Orchideæ are familiar examples. But there are general considerations which show how limited insect aid must be. The flowers of the Rocky Mountain region are beautifully colored; but Fremont

pathetically describes the solitary bee that rested on his shoulder on the top of Pike's Peak. On my first visit the comparative absence of insects proved very annoying to the entomologists who accompanied me. It was a frequent subject of conversation whether Fremont's Bee was not apocryphal, and though a visit some years later found some humble bees on *Polygonum bistorta* on Gray's Peak, enabled me to do justice to the veteran explorer, the incident shows how rare such insects are. Indeed the paucity of animal life of all kinds in the Rocky Mountains is well known; but there is no more scarcity of seed in the colored flowering plants, than in similar ones elsewhere. Nearer home we see the same thing. In many of our woods spring flowers abound, but any observer of woodland flora must have been struck, especially in early spring, with the rarity of insects about them. But all these plants, without any remarkable exceptions, seed well. Again red clover fields are favorite pasture grounds for humble bees, but when, as is the case in my vicinity, the white clover abounds in blossom, they totally abandon the red clover fields. I have watched red clover fields carefully several times a day for a week at a time, after their abandonment by the bees, without seeing any thing but a few, very few, diurnal Lepidoptera on them occasionally, and certainly of no consequence for fertilization to this immense extent, yet the flowers bore seed as fully as the most insect-frequented field would do.

General evidence of this kind is, I think, fair presumption against insect agency to any material extent.

But the direct and positive evidence is what we want; and here I find it in great abundance. Many flowers are so constructed among the so-called entomophilous class, that they must of necessity fertilize themselves. I do not refer to the cleistogamous plants, which seed without perfecting their corollas, but in regular flowers where it is not usually suspected. In *Melampyrum Americanum* the curved apex of the pistil is clasped by the stamens, and held in contact with the pollen just as in a cleistogamous violet. A large number of plants have their pistils covered by their own pollen before the flowers open. Of these I have especially for this paper gone over observations previously made with species among Wistaria, Glycine, Cercis, Genista, Lathyrus, Colutea, Ballota, Leonurus, Phaseolus, Pisum, Linaria, and some others. This is particularly the case early in the season; later

the pollen sacs burst more generally about the same time with the opening of the corolla. It may be objected that the covering of the stigma with pollen is not fertilization, as it requires a peculiar condition of the pistil to receive it. But pollen has a long vitality. Carriere has found its fertilizing power unimpaired after three months old in one species, and other cases have been recorded. Not to leave this point open, I had some unexpanded flowers of *Wistaria sinensis* examined by my friend, Dr. Gibbons Hunt of Philadelphia, the accomplished microscopist, who reports that the pollen tubes had actually made their descent through the pistil towards the ovarium.

But what I regard as remarkable is that many flowers which have been taken by European observers to illustrate the necessity of insect fertilization, not only fruit abundantly, when they are fertilized before they open, but in many cases fruit when not visited by insects, and in some cases, as in *Melampyrum*, have arrangements for self fertilization. Thus Dr. Farrar's observations on the Garden Bean, in 1869, Dr. Ogle's in 1870, on the Scarlet Runner, Mr. Bennett's on the Pansy; and I think I may include Mr. Darwin's on Clover, and those by the author of this paper on *Linaria vulgaris*. In my garden, I have rarely seen an insect on the Common Pea; yet every flower bears its pod. Its pistil is clothed with hairs on the upper surface, and curved towards the standard, with the anthers on the upper side. As soon as the anthers burst, they pass downward, brushing their pollen against the stigma and covering it with it. The Lima and Bush Beans are also rarely visited on my grounds, where clover abounds; but are abundantly fertile. The pistil protrudes in many of these papilionaceous plants, as noted by authors above quoted, when an insect or any pressure is made to bear on them; but it will be found that in many cases, the very movement makes them clutch as it were their own pollen. In the Violet and Pansy, the lifting "apparatus" certainly throws the pollen on the entering insect's back; but only to draw it against the stigma on the exit. In the White Clover Mr. Darwin's experiment nearly staggered me. It is so rare there is any mistake about his facts. He says he protected some from bees, and they bore no seeds; some exposed to bees perfected thousands. I am satisfied that in all cases I examined of flowers just before expanding, and before any insect had interfered with them, the pistil had received its own pollen. Mr. Darwin does

not say how he protected his flowers. Nutrition is often interfered with by "protection;" and failure to seed follows. I endeavored to repeat the experiment of protection for this meeting. I covered a patch of clover with a sieve having one-eighth inch meshes. No bees could get to them. I think I may say every flower perfected seed. Unfortunately I found on one examination a small sand-wasp had ventured through, and was collecting pollen from a flower. I do not think any but this one entered, still it diminishes seriously the value of the experiment. I do not care to take the time of the meeting to refer in detail to the immense number of plants which cover their pistils with their own pollen, and which must limit seriously the extent of the entomophilous class; as any one, and I hope he will look, can find them easily. Even Müller himself admits that the four short stamens in *Hesperis tristis* is for self fertilization, in case the two long ones should fail to meet with insects, for whose use he thinks they were intended, and this ought to be as true of all tetradynamous plants. And yet so thoroughly has the idea that all petaloid flowers must have insect aid, that because a plant of this class brought to prominent notice by the Challenger expedition, a *Pringlea*, was apetalous, Dr. Hooker was led to suggest that it must have the pollen of anemophilous plants. As this was found to be so, it is regarded as confirming that view, and yet with us *Thlaspi bursa-pastoris*, which has no visiting insects of consequence with us, has abundance of seed as the horticulturist knows to his great annoyance.

Indeed the interpretation of the uses of structure often has two sides. I believe I was among the first to suggest that the lever-like false anther in *Salvia* was an aid to cross fertilization through insect agency, yet I subsequently noted in the "American Naturalist" for 1871, that if the plant had "sense" enough to plan such a contrivance, it parted with that good sense in *Salvia involucrata*, where the contrivance is perfect, but a subsequent patent spoiled the first. The *Lobelia* is a much used illustration of the beautiful contrivance to insure insect agency. I confess I do not understand how self fertilization is accomplished here, but I do know that *L. erinus*, entirely protected from insects under glass, seeds abundantly. Professor Gray says of *Habenaria tridentata*, that in this species the summit of the sterile anthers receive pollen and are penetrated by pollen tubes; how far similar processes extend in nature, it will do no harm to consider, though out of place somewhat in a paper in which speculation is not in order.

But suppose that cross fertilization by insect agency be all that is claimed for it? Let us grant that there has been an effort on the plant's part to avoid self fertilization, and to effect cross fertilization by insect aid. The question follows, what has the plant gained by it? If it is not proved that in-and-in breeding — self fertilization — is a detriment to continuous existence, the case, theoretically, is gone. But we have facts. *Specularia perfoliata* is said by the books to have its earlier flowers cleistogamous; but this is only so in open places. In shady situations all the flowers are of this character, and it is wonderful how productive and strong they are. I know an open wood in which the plant is a peculiar characteristic of the surface vegetation. I never saw one petaloid flower on these plants. Most of the seminal increase in the Violet, especially those which grow in woods, in those which produce cleistogamous flowers, is from this class. These species have held their own better, are more widely distributed, are in greater numbers, than those which depend on increase from petaloid flowers alone.

In any theory of the survival of the fittest, we must take those to be the most fit to survive, which produce the greatest quantity of seeds, all other conditions being equal. A plant which perfects a thousand seeds, will have a better chance of posterity than an individual of the same species that perfects but a hundred. If a plant thought, as one might almost say in view of popular theories, that it would gain any benefit by escaping from possible injury through in-and-in breeding, and thus changed its structure so as to favor only fertilization by insect aid, we see at once that it places itself in the position of all of us who give up to others the doing of our own work,—it is often not done at all. This is actually the case with non self fertilizers. The *Geranium* is an example within general reach. In my garden I have paid most attention to *Geranium sanguineum.* The petals expand before the rupture of the pollen sacs. Five stamens elongate, and no sooner have they reached their full length, than the pollen cases burst and the anthers fall off. The other five follow in the same way, all before the pistils have made their full growth. The filaments are persistent, close up among the pistils, and seem really in their utterly useless condition to say that something had gone wrong with the plant in its efforts at cross fertilization. The seed time tells the same story. More than half the flowers are without seed, large numbers with only one out of the five, and very rarely

indeed are the full five carpels fertile. It may be said this is not its native country; insects in its own would have paid more attention to their duties. But granting this, it has lost the power which a self fertilizer possesses of taking care of itself both at home and abroad. What has Yucca gained? It is one of the most local in its distribution. Each species is confined to limited areas in comparison with self fertilizers. Some seasons when the insect fertilizer is scarce, as insects of many species often will be, there is barely a seed, as I have witnessed myself in the chief localities for *Yucca angustifolia* in Colorado. Indeed its existence depends on its persistent roots. If it were an annual I believe the whole genus would now be well nigh extinct. It is the same with Orchideæ, another family that has a difficulty in self fertilization. If one, without regard to any theory, but in the light of well known facts in botanical geography, were to be asked which family he thought the most likely to first disappear, I think he would say Orchideæ. They must stay where their especial insect lords are, and they have to endure the great chapter of accidents, without the chance of escape to foreign lands. Surely we see that self fertilizers have the advantage in the great struggle for life. If we were to credit plants with a common sense with which in some quarters they have been almost invested, I think we must award the point of greatest wisdom to those which catch insects and eat them, rather than to those which dally with them to their own final ruin.

There are plants which cannot fertilize themselves; but why must we be driven to the opinion that this is a selection,—a choice? May it not be rather what popularly we should call a necessity? In the course of ages may there not be a failure of nutritive power which would interfere with the relation of the sexual organs? This suggestion is borne out by facts. I have already shown the members of this Association by numerous facts in several papers, that the male and female sex in plants, that is whether the male or female organs in the flower are most favored in development, is wholly a question of nutrition. In this paper I have shown a similar law. In the earlier flowers of the season the anthers usually, in many species, burst just before the flowers open. Later in the season when vitality is nearer exhausted the male has not the same active development, and perfects its pollen only after the expansion of the petals. This overlooking of vital

power, and looking to fertilization merely for fruitfulness, is I believe one cause of error in the discussion of the present question. A flower has perfect pistils and stamens. It does not fruit, therefore it was not fertilized. This is the argument. Indeed I may here quote again the exact language of the author from whom I took my text. "Farmers on the banks of the Rhine reported, years ago, that orchards in which bees are reared are more productive than those in which there are none." But American experience now is as good as Rhine experience long ago. Our orchards are often white with bloom, and hardly a fruit follows; and again very few flowers, but most of them set. There may be no difference in the number of bees about them. It is wholly a question of how favorable were the influences of nutrition on the maturing flower buds the fall before. I have already shown that the Wistaria is actually fertilized by its own pollen, and yet it is notorious that the Wistaria rarely seeds in this country, the forces of nutrition not favoring it. Very slight local causes often determine these matters. I once had a very large white Noisette rose, called "Woodland Margaret," trained to the roof of a greenhouse in which was abundance of light, though little sunlight; but it would not flower. In summer, however, a few branches would get through a ventilator kept open, and these always blossomed freely. All cultivators of winter flowers know the influence which direct sunlight has over reflected light in the formation of flowers. So a ringed branch produces flowers, when one untouched does not. This illustrates the influence of varying phases of nutrition on the floral organs, and I have no doubt that the difference in the conclusions arrived at by Mr. Darwin and myself in white clover, would be accounted for in this way, if all the circumstances were known. Many instances illustrating this nutritive influence might be given. I will give but one more. In our region the *Cercis Canadensis* is very irregular in seeding. A tree this year loaded, may not have one seed vessel next year. In older times "late frosts" furnished the explanation, but more recently imperfect fertilization. I have a row of fifty-two trees about fifteen years old. These are all apparently alike in general health and vigor. Most have no seeds; but nine have a profusion. They were all exactly alike as regards fertilizing conditions. Some peculiar phases of nutrition aided the productive trees.

I have not thought it necessary to occupy your attention by a

long array of facts. What I have adduced is sufficient I trust to prove: —

First; that the great bulk of colored flowering plants are self fertilizers.

Secondly; that only to a limited extent do insects aid fertilization.

Thirdly; self fertilizers are every way as healthy and vigorous, and immensely more productive than those dependent on insect aid.

Fourthly; that where plants are so dependent, they are the worse fitted to engage in the struggle for life, the great underlying principle in natural selection.

CARNIVOROUS PLANTS. By W. J. BEAL, of Lansing, Michigan.

THIS is a new term which has lately been applied to plants that catch insects by various contrivances.

In 1768, over one hundred years ago, Mr. Ellis discovered that the Venus fly trap of North Carolina, catches insects by a peculiar construction of the tips of its leaves like a steel trap. Numerous experiments have satisfied botanists that flies are not only caught, but digested by a fluid poured out by the plant, and the materials absorbed into the tissues of the plant. In 1780, ninety-five years ago, the sun-dew (*Drosera*) was found to catch insects by its sensitive hairs with a sticky gland at the end of each.

Drosera rotundifolia, a common little plant of our marshes has a round leaf, about the size of a cent, sometimes containing eighteen small flies. The glandular hairs move towards the fly when irritated.

Drosera longifolia has a very long slender leaf also covered with glandular hairs. It rapidly coils up from the tip catching flies which it devours and absorbs.

North America has eight species of pitcher plants (*Sarraceniaceæ*), the leaves of which catch insects. They have stiff hairs inside pointing downward which prevent the escape of most insects. Some have a sweet secretion below the opening at the top on the outside. This grows sweeter and sweeter and more abun-

dant, till it comes to the opening, to entice foolish flies to the fatal pit whence no fly ever returns.

Catesby, some years ago, thought these pitchers were an asylum for insects to escape from frogs and other animals. I have here some fresh specimens of *Sarracenia purpurea*, the only pitcher plant found in our state. Pouchet, in his popular book, "The Universe," speaking of this plant says, "The leaves rise from spot to spot at the feet of the traveller, and are filled with pure and delicious water, for the benefit of which he is all the more grateful that he is encircled by nothing but marshes." The truth is the water abounds in rotten bugs and worms.

Of *Nepenthes*, there are some thirty species, most of which secrete honey on some parts of their pitchers, to entice insects which they catch and devour.

The spathe of *Alocasia* catches, it is said, slugs and destroys them in a strong secretion. For a full account of the above interesting plants, see Dr. Hooker's Inaugural Address, last year, at the British Association, printed in "Nature" Vol. 10, p. 366.

Pinquicula catches insects.

According to Mrs. Treat, bladderworts (*Utricularia*) catch infusoria and other small animals. These are taken by strange devices in the little bladders which work some like miniature eel traps. The animals are dissolved and contents absorbed by the plant. In addition to the above, we have quite a large number of other plants belonging to diverse Natural Orders, which catch insects. The young leaves and stems of *Rhododendron* is one of them. A species of *Plumbago* in the green house, sent from the Agricultural Department at Washington, has viscid hairs about the flowers, large enough to catch and hold a common house fly, even if caught by one or two legs. Several species of *Polanisia*, *Cuphea viscosa*, some species of *Physalis*, and *Solanum*, catch small insects by sticky hairs on the younger portions of the plant. Many species of *Silene* attract, catch, and hold insects to such an extent that the genus goes by the popular name of "Catch fly."

Lychnis vespertina, a kind of cockle sometimes in our wheat fields, also takes small insects. It seems to digest them by the small glands at the end of the hairs. We need not necessarily suppose that they are digested because they are captured by sticky plants.

The large bud scales of the horse chestnut and balsam poplar,

in the spring of the year are often found holding insects by the sticky varnish with which the buds are very copiously covered. We see that the varnish may be of use to protect the inner delicate parts of the bud from the inclement weather, but I am unable to see that insects are of any advantage to the plant when so caught. The dry bud scales are sticky for a purpose which we can readily understand. The flies are most likely accidentally caught. Possibly this is the case with some other plants which catch insects by a sticky secretion or other contrivance. I have lately given some attention to the *Martynia* on account of the great numbers of small insects which it catches by glandular hairs. On August third, I counted seventy-six small Diptera and some other insects on the upper side of a young leaf of about four inches average diameter, and two hundred on the under side. The insects are caught on all parts of the plant which are exposed, on the stems, on the calyx and corolla, including even the throat of the corolla. Among a lot of others, was one plant about three feet high, spreading three feet in diameter, which, according to estimate had 7,200 (seven thousand two hundred) small flies on it at one time. The hairs are very numerous all over the surface. None of them are sensitive as I can find. They vary exceedingly in length, from $\frac{3}{16}$ (three-sixteenths) of an inch to $\frac{1}{100}$, or even shorter. Some of them have as many as ten cross partitions. The contents of these cells appear quite clear, except one near the top, next to the top cell. This is larger than several of those below and contains chlorophyll. It seems to be something like a gland. Above this is a larger cell, with perpendicular *striæ* along its sides. When fresh and undisturbed the top is nearly spherical and resembles a small drop of dew. The secretion is quite copious and exceedingly viscid with an unpleasant odor. I placed some small fragments of raw beef on the glands one morning, but the sun seemed to dry them up, much as it did those left on blades of grass which had no glands. I placed some very minute portions on the glands in a spot sheltered from the direct rays of the sun. In some cases, the whole of the piece of beef disappeared.

The small insects seem to live but a short time although they are touched by only two to four hairs. The substance seems to be soon taken out of the insects. In my opinion, it is a true insectivorous plant.

INEQUILATERAL LEAVES. By W. J. BEAL of Lansing, Michigan.

I WISH very briefly to call attention to the inequality of the lobes of many leaves and leaflets, as shown in a paper prepared for, but not presented at, the meeting of this Association held in Indianapolis; also to make some additional remarks.

Many leaves have an equal part each side of the midrib, as in the grape. Begonia, hackberry, red elm, American elm, and basswood have alternate two-ranked leaves with the upper or inner lobe fullest.

The witch hazel has alternate two-ranked leaves with the lower or outer lobe fullest.

The beech, hazel, mulberry, grape, have alternate two-ranked leaves with equal lobes. The side leaflets of the bean, black ash, hickory, elder, poison ivy, are fullest on the lower side. The leaflets of Ailanthus are fullest on the upper or inner edge at the base.

Along the middle of the leaflets of the southern prickly ash, they are fullest on the upper side. Those of the northern prickly ash are fullest on the lower side. *Rhus toxicodendron* has the lower edge of the side-leaflets fullest. *Rhus copalina* the reverse of this.

The opposite leaves of *Cornus Florida* are fullest on the lower edge of the side branches when they are turned horizontally. The opposite leaves of several euphorbias are the reverse of *Cornus*. The two opposite bracts of the blue beech are fullest on the side away from the main axis.

The leaves of common sheep sorrel usually have one lobe the larger. In the cotyledons of buckwheat, each is fullest on its left side so they will not match each other till one is turned over.

At the proper age the axis of our common four o'clock is terminated by a flower. On each of the two opposite branches are two opposite leaves, each of which is fullest on the side next the flower.

Two opposite leaves of the *Martynia* have equal lobes. The next two above, at right angles to these, have equal lobes. From the axile of each of these four symmetrical leaves comes a branch. Each branch has a small roundish symmetrical leaf next the main axis. It has a longer and larger symmetrical leaf pointing away from the main axis. At right angles to these and below them on each branch is an unsymmetrical leaf with the fuller lobe toward the main axis. These rules seem to apply to all cases, but in the younger or succeeding branches, the subject sometimes becomes still more complicated, on account of the non-development or unequal development of some of the branches.

The leaves of *Datura* are very similar to those of *Martynia* as to equality of lobes.

In *Physalis* or ground cherry, the leaves are geminate; a larger leaf usually standing by the side of a smaller one. A few of the leaves on the main axis and others have equal lobes, but most of them have unequal lobes.

The plant sends out branches quite irregularly. I have made numerous diagrams, but have not been able to make out the rule or law for this inequality of leaves in *Physalis*, yet I believe there is some rule about it that will yet be discovered.

Solanum nigrum and *Capsicum annum* have leaves somewhat like those of *Physalis*. Why these leaves have unequal lobes I cannot see; and I have no theory to offer as a probable explanation.

THE VENATION OF A FEW ODD LEAVES. By W. J. BEAL, of Lansing, Michigan.

PLANTS bearing pedate leaves, like those of the dragon root, are rare in our country. The petiole separates at the top into three branches, the middle one containing a single pinnate leaflet. The two side branches each divide again and again five or six times, each bearing a leaflet on the upper side. I have found several simple leaves which are pedately veined. One of them is the leaf of the *Martynia* and is here represented. If we cut it down between the chief ribs, we shall have a pedate leaf like that of the dragon root; or if we fill up the space between the leaflets of dragon root we shall have a pedately veined leaf as in Martynia. It is only a short step from leaves of Martynia to those of the maple and grape vine. We can find any number of intermediate forms.

The leaf of the ginkgo tree (*Salisburia adiantifolia*) has often been noticed as quite peculiar. I have never seen the morphology of its leaves satisfactorily explained. Probably I may not explain them correctly. At the apex of the petiole it seems to divide and gracefully spread each way extending along the margin of the leaf. From these side ribs pass off numerous veins to the upper margin of the leaf. The middle at the top is often lobed or cut one-third or more of the way down. The leaf looks much like

some of the pinules of the maiden hair fern, hence one of the names applied to the plant, "maiden hair tree." How does this ginkgo leaf correspond to any other leaf? At the base of the leaf the veins all seem turned out or over each way. If we split the leaf down from the top, as already started, and turn the two halves over, we bring the two half midribs together; we straighten the twisted bundles of veins and get a leaf with veins like those of the canna or banana.

I here make use of an erroneous illustration found in several botanical works. It seems, the artist thought it ought to be this way and so made it. It shows the morphology of the leaf of ginkgo as I understand it. The very young leaf at the end resembles a cup split down and the two edges turned in. The pinules of the maiden hair fern are not similarly twisted, but show their morphology to be pedately veined, like the leaf of Martynia, except there are no cross veinlets in the fern. The leaf of the maiden hair grows right side up. That of the ginkgo wrong side up, with its midrib split in two, and each half along the outer edge of the leaf.

SOME OBSERVATIONS ON THE STRUCTURE AND HABITS OF UTRICULARIA VULGARIS (carnivorous? plant). By THEO. B. COMSTOCK, of Ithaca, N. Y.

ABSTRACT.

DURING the recent session of the Kirtland School of Natural History in Cleveland, specimens of *Utricularia vulgaris*, one of the common bladderworts of Northern Ohio, were studied by myself in the laboratory, under the microscope, for the purpose of giving the pupils some ocular demonstration of the supposed carnivorous habits of the bladders, which in this species are less than one-quarter of an inch in length. The shape of the bladder is peculiar, and in the smaller *U. neglecta*, described by Dr. Darwin in his new work on "Insectivorous Plants," this has been ascribed to mimicry, as it is thought to resemble some forms of minute *Entomostraca* upon which it apparently feeds. In the present instance, this does not hold good, as the size of the bladder is much larger than its prey. The mouth of the sac, in section, resembles

one form of drain tiles, flat on the bottom and arched above, and the flat portion is always below when the plant floats naturally. Within the mouth, a hinged valve rises upward and backward from a fold (the "peristome" of Dr. Cohn), fitting closely so as to prevent the exit of anything which once passes inside the bladder. The valve is covered, or studded, with small glandular bodies raised upon pedicels, and beautifully arranged in parallel curves following the course of the rim of the valve. From the external wall of the bladder, several finger-shaped bodies, or tentacles, protrude in front of the vestibule. These are celled, and, so far as I could detect, not at all sensitive, although frequently brushed by small animals swimming near them. On these antennæ, as they have been called, minute fragments of *Chara*, and similar material frequently collect in considerable abundance. I saw no animals enter the bladders, but specimens of *Cypris* and *Paramœcium* were found swimming within some of them. The *Cypris* in particular seemed affected injuriously, generally moving irregularly, with uncertain movements, as if benumbed or weakened. The mouth parts are certainly well adapted for enticing and entrapping the smaller forms of aquatic life, which abound in the localities where this plant is commonly found. The value of this paper is slight, except as confirmatory, in a measure, of the discoveries of others, and as an illustration of the great ease of conducting similar observations now much needed.

PERIODICITY IN VEGETATION. By JAMES HYATT, of Stanfordville, Duchess Co., N. Y.

THE development and the life of the plant have various relations to time: relations determined or modified more or less with each species, by surrounding circumstances and influences.

Several classes of periodic relations may be specified. One class might embrace all those which are subject to modifying agencies, and another might include those which are independent and absolute. In these, different species of plants will stand in

various lights. The same species of *Gossypium* may be an annual in a higher latitude, but a perennial in tropical localities. *Ricinus communis*, the castor-oil plant, affords a similar example.

With these, the seasons, the temperature, etc., determine the life period. By experiments in selecting different localities, climates, etc., in the cultivation of a plant, we learn how far periodicity of this kind is absolute. We might infer from the restricted boundaries of the province, in which some plants naturally dwell, that it would be impossible by a change of habitat, or by any variation of circumstances, to make them perennial.

The *Cakile Americana*, or American sea-rocket, might prove to be an absolute or true annual.

Some plants have such an inflexible nature, that when the necessary relations are not supplied, they die; they do not accommodate themselves to any considerable variation. Others like *Stellaria media*, the common garden chickweed, flourish on the Eastern or the Western Continent, in northern or in southern latitudes, and blossom and ripen fruit, throughout almost every season of the year.

It would be interesting to study how far some of the minor features of plant life might be made to change their periodic relations. Could we contrive to retain in position the caducous sepals of *Sanguinaria Canadensis*, while carrying forward the plant, to the perfection of seed capable of germinating? or could we, by prolonging the darkness, induce the *Oenothera biennis* to retain its flowers for more than the usual period? since it appears to be obscuration of the light, rather than the regularly recurring night and day, that determines the opening and the closing of this miscalled "evening primrose."

Another interesting line of inquiry arises as to the possible length of the whole life period, with certain perennials. We are scarcely able to determine how long a *Castanea vesca*, or an *Olea Europæa*, may live, since it is claimed that on the eastern Continent, individual chestnut and olive trees have been living for very many centuries; and our California *Sequoyas*, or gigantic redwoods are of the same category. It seems probable, from all our experience, with shorter lived species, that under the most favorable circumstances possible, there is a limit, perhaps a definite one, to the life of every plant. There is ample room, however, for investigation here.

At the Hartford meeting last year, I presented some account of certain facts which have forced themselves upon my notice, and which seem to indicate that there may be *a periodicity of seeds.* I refer particularly to the very singular behavior of a patch of *Silene antirrhina*, a slender "catch-fly."

This patch is somewhat isolated, has an area of two or three square yards, is bounded on one side by an artificial water course, with precipitous rocks rising beyond; while on the other side is a line of stones, somewhat lower ground, and a permanent brook. The patch which is on my own grounds, is left undisturbed, in every respect, by both man and brute.

This catch-fly appeared here in considerable numbers, flourished, flowered, seeded, and died down, in 1864, in 1869, and in 1874; while not a single plant has shown itself, neither in 1875, nor in any other year than those specified since 1864. I have not heard of any plants of this species within a mile of this patch.

So far, it seems that these annual plants spring up every five years; but that their seeds lie dormant through the intermediate period. I shall be very glad to hear how *Silene antirrhina* behaves in other localities.

Several other plants have furnished indications of a similar character. I have noticed that *Lobelia inflata*, in the same neighborhood, is very abundant in certain years; while for an intermediate period of several years, there is comparatively little of it. As this plant grows in pasture fields, where there is a rotation of crops, I have been disposed to think that this *Lobelia* might come in, after the seeding down to grass which follows the series of grain crops; but from recent observations, as the plant is very abundant this year, in all the fields around, vastly more abundant than for several years before; and this in different fields, each of which varies from the adjoining ones as to the number of years since the "seeding down;" I am disposed to think that the Lobelia is independent of the rotation, to a certain degree. I have now commenced to note dates for this plant, and may be able to report some result, hereafter.

It would be very interesting to experiment with different species as to this point. To make the experiments fair, each species should be placed in an isolated patch, should be left to itself, and all the seed sown should be derived from the same individual, so as to introduce no discordant elements as to periodicity.

Having kept a botanical journal for many years, in which I have attempted to note down the beginning of the flowering season for each species, for each year, with the more common plants with which I meet, in the regions which I frequent, I have been interested to compare these notes, in relation to the forwardness of the spring season, for the last ten or twelve years.

As the early portion of the spring of 1875 was evidently very much retarded, I was the more disposed to make this comparison.

Throughout these years, I have been accustomed to make a weekly trip, from my residence in Central Duchess County, N. Y., by way of Pokeepsie or Fishkill, which are adjoining Hudson River towns, and thence, along the east bank of the Hudson, to New York City; often stopping by the way at several points, and not infrequently visiting other points on the west shore. Thus, weekly, throughout nearly the whole of the year, I have made a rapid reconnoissance of this region, and jotted down botanical notes in a pocket diary, to be transferred and enlarged in a permanent journal.

The distance traversed is nearly one hundred miles. Before returning from the city, where I spend several days each week, I visit, either alone or with other members of the "Torrey Botanical Club," various points in different directions around the city; thus viewing something of the progress of vegetation; around New York.

The lateness of the early spring of 1875, was partly due to the fact that in the beginning of the previous winter, severe cold weather preceded the snows, and the ground became very deeply frozen. In Duchess County, water in pipes buried four feet beneath the surface was frozen solid; while in New York City, I have never known so much freezing of the pipes for the Croton water supplied to houses, as in 1875.

From whatever causes, the early spring of 1875, in these localities, was very cold, and the progress of vegetation was very much retarded. By comparing the flowering of the twenty-one following plants, for a period of ten years, with that for 1875, this retardation is distinctly shown. These plants, as nearly as I can estimate, from my notes, succeed each other in the order given, in the regular opening of their flowering season. The average date, for the number of years specified of this opening is also given.

TABLE.

AVERAGE DATE OF THE COMMENCEMENT OF THE REGULAR FLOWERING SEASON, FOR THE NUMBER OF YEARS SPECIFIED FROM 1864. THE YEARS 1866 AND 1875 NOT BEING INCLUDED.

NO.	NAME OF PLANT.	DATE.	TIME.	LOCALITY.
1.	Draba verna..........................	March 26.	For 5 years.	New York City.
2.	Symplocarpus fœtidus................	" 29.	" 9 "	Duchess to Westchester.
3.	Veronica hederæfolia................	April 1.	" 4 "	Northwest Hoboken, New Jersey.
4.	Alnus serrulata......................	" 2.	" 9 "	Central Duchess County.
5.	Acer rubrum..........................	" 3.	" 8 "	" " "
6.	Ulmus Americana....................	" 8.	" 5 "	" " "
7.	Claytonia Virginica..................	" 9.	" 5 "	West Hoboken, New Jersey.
8.	Populus grandidentata...............	" 10.	" 7 "	Pokeepsie, New York.
9.	Salix eriocephala.....................	" 11.	" 7 "	Central Duchess County.
10.	Hepatica triloba......................	" 12.	" 10 "	" " "
11.	Corylus Americana..................	" 13.	" 8 "	" " "
12.	Dicentra cucullaria..................	" 14.	" 9 "	Ulster County, New York, to West Hoboken.
13.	Saxifraga Virginiensis................	" 15.	" 10 "	Central Duchess to New York City.
14.	Populus tremuloides..................	" 16.	" 1 "	Central Duchess County.
15.	Arabis lyrata.........................	" 17.	" 5 "	Pokeepsie to New York City.
16.	Erodium cicutarium..................	" 18.	" 2 "	Pokeepsie.
17.	Tussilago Farfara....................	" 18.	" 5 "	Central to Southwest Duchess.
18.	Caltha palustris.......................	" 19.	" 9 "	Central Duchess.
19.	Antennaria plantaginifolia...........	" 20.	" 6 "	Central to Southwest Duchess.
20.	Dirca palustris........................	" 21.	" 1 "	Central Duchess.
21.	Magnolia conspicua..................	" 22.	" 9 "	Pokeepsie.

Duchess County extends from the Hudson River to the Connecticut line, touches Massachusetts at the Northeast, and is midway between the cities of New York and Albany. Ulster County lies directly west of Duchess County; while Putnam, Westchester, and New York Counties succeed Duchess going southward.

Rejecting three of the foregoing plants, and taking the averages of the remaining eighteen for the number of years mentioned, they commenced to flower in 1875, $21\frac{5}{8}$ days later than the average for the whole of them since 1864.

Also, the average of their opening flower-season in 1875 was thirty-four days later than in the earliest spring for the preceding ten years.

This opening was more than eight days later than in the latest spring for the same period.

With single species of these plants, the greatest differences were more than six weeks, for this period of ten years.

I have no available notes for 1866, so that year is omitted from all notice in this article.

If the early spring seasons for each of these years are compared as to the regular opening of these flower-seasons, the following results are shown by the notes of my journal.

In the spring of 1865 was the earliest beginning of the flower-seasons, and that of 1871 came next.

I estimate that 1870 was a mean year in this respect, that 1874 was somewhat late, that 1867 and 1868 were about equally in a degree later, that 1864 and 1872 were later still, that 1873 was yet later, that 1869 was the latest of all these, and all were exceeded by 1875.

In tabular form these years will stand thus:

EARLY YEARS.	MEAN YEAR.	LATE YEARS.	
1st, 1865.		1st, 1875,	latest.
2nd, 1871.	1870.	2nd, 1869,	next.
		3rd, 1873,	next.
		4th, 1864, 1872,	next.
		5th, 1867, 1868,	next.
		6th, 1874,	next.

I also estimate, that as we go farther back in date, a larger proportion of early spring seasons will appear, within certain limits.

In the early spring of 1875, different species of plants were not affected alike. Those which root more deeply were more retarded. *Hepatica triloba*, in 1875, was sixteen days later than the average for the ten years; but *Acer rubrum* was retarded twenty-six days, and the other species of the maples were very late.

Later in the spring the retardation was much less. *Symplocarpus*, in 1875, was retarded twenty-six days after its average flower-opening on the 29th of March; but *Caltha*, growing in similar situations, in the same locality, was retarded but eighteen days; its average flower-opening being estimated at April 19th. *Magnolia conspicua* was also retarded in 1875 for eighteen days beyond its average.

Some plants, like *Taraxacum dens-leonis*, have two general flower-seasons, one in the spring, and another quite marked in the autumn, when similar conditions as to temperature, etc., prevail. Between these, there are a few scattering flowers through the summer.

I have taken no account of the flowering of exceptional individuals, in these estimates. We sometimes have "dandelions" and violets in flower in January, and I have a record of a symplocarpus in Pokeepsie in flower, March 4th.

A thin scattering of dead brush, some distance above low plants, with other favorable conditions, will aid to bring flowers forward very early. These branches perhaps absorb and re-radiate rays, both from the sun and the earth, and so prevent vicissitudes.

In my Botanical Journal I adopted, several years ago, a scheme for noting the flowering stage and the growth of the fruit. For the former, I use a *decimal expression* thus:

1. Flower buds just distinctly visible without magnifying.
1.5 Flower buds half grown.
2. Flower buds full size.
2.5 Flower buds half open.
3. Some flowers open and some mature pollen. This is the beginning of the flower-season.
4. Flowers quite generally open.
5. Mid-flowering season.
6. A slight decline.
7. A more marked decline.
10. The last flowers of the season.
11. No more flowers.

For the fruiting-stage I use *an expression* in the form of a *vulgar fraction*, to prevent mistakes, thus:

$\frac{1}{10}$ Fruit one-tenth its full size, in diameter.
$\frac{5}{10}$ Fruit half grown.
$\frac{10}{10}$ Fruit full grown.
$\frac{11}{10}$ Fruit generally ripe but not fallen.
$\frac{12}{10}$ Fruit generally fallen from the plant.

In conclusion, I wish to point out to all who have the slightest interest in Botany, the advantage of a pocket diary, always at hand, for chance notes, and the transferrence of these, with amplifications, into a permanent Journal, in which are entered dates, localities, flowering and fruiting stage, personals, and other essentials; noting particularly, for each year when possible, the commencement and the close of the flowering season for each plant.

In this way a most interesting, valuable, and reliable amount of botanical knowledge is accumulated. Its importance is progressively enhanced, and it is always available for the determination of questions which arise. I regret that I did not begin this at the very commencement of my botanical studies.

Ancient Rock Inscriptions in Ohio. By Chas. Whittlesey, of Cleveland, Ohio.

ABSTRACT.

At the Indianapolis meeting in 1871, I exhibited a sketch of the sculptured rocks near Barnesville, Ohio, made in 1859 by Jas. W. Ward, Esq., of Cincinnati. More complete copies have since been taken for the Western Reserve and Northern Ohio Historical Society by Dr. J. W. Walton of Barnesville, which I now exhibit.

The effigies are first filled with paint, when a sheet of muslin is spread over the rock and pressed into the depressions. This mode gives the exact size and outline of the figures, but does not represent their actual or comparative depth; some are very shallow, scarcely discoverable to an unpractised observer; others are well defined and from an inch to an inch and an half deep. On the

Berea sandstone and on the grits of the coal series, the marks of the tool used in cutting away the rock still remain.

On limestone no tool marks remain because this rock is dissolved by long exposure. In every instance where artificial marks of the tool remain they are those of a pointed instrument like a dull pick, but no tool has yet been found that can be said to have been made for this purpose. Probably a fragment of flint, quartz, or other hard stone was used, large enough to be grasped in the hand, having sharp corners. A pick of horn or bone with a hard stone or flint point inserted in it, like those of the ancient Swiss Lake dwellers, would do the work very well, but nothing of the sort has been found here. A pointed tool of native copper with a socket to receive a haft or handle was discovered on the Flint Steel River of Lake Superior in 1865, by Gen. Walbridge of Detroit, which I described in Tract No. 11 of the Western Reserve and Northern Ohio Historical Society for August, 1872. This was probably used for mining purposes in the ancient copper mines of that region, and would answer the purposes of sculpture on our rocks.

Sheets Nos. 1 and 2 are tracings of the Barnesville track rocks on the horizontal surface of the rock.

No. 3 is a tracing of a portion of the characters on a vertical face of the Logan sandstone of the Ohio Reports, near Newark, Ohio. This is the work of Dr. J. H. Salisbury and Mrs. Salisbury in the year 1860, on the plan above referred to, by which the subsequent tracings of the Historical Society have all been taken. This sheet was exhibited at the Indianapolis Meeting in 1871.

Nos. 4 and 5 were taken in 1873, by myself, from a flat rocky surface in Amherst, Lorain Co., Ohio. It is a portion of the grindstone or Berea grit beneath the coal series.

No. 6 represents several groups of rude carvings, on some isolated granite rocks in the Susquehanna River near Columbia River, Penn., known as the Big and Little Indian rocks. These tracings were made in June, 1872, by Mr. L. C. Cordes of Harrisburg, Penn.

This copy was taken by Mr. Cordes with great care and labor, and with it he has furnished a full description in writing. Mere pencil sketches of these effigies we have found to be of no archæological value, as any one will perceive who compares this tracing, with the published pictures of this rock.

For the purpose of publication our Society reduces the muslin sheets by photography to the size used by the engraver.

My object is not at present to discuss the meaning or the value of these inscriptions, but merely to preserve such of them as have not been destroyed.

By this mode of making copies we present a representation of the originals that can be relied upon as perfectly accurate. If all archæologists and societies in the United States will do as much for their respective localities, the rock inscriptions of North America can be discussed in an intelligent manner.

A large part of them are no doubt the work of the existing red race, and probably have only a local, personal and temporary meaning.

Although as yet nothing like ancient alphabetical characters has been found in the United States, these pictorial records have an interest and one that will not diminish by the lapse of time, or the disappearance of the race which made them.

On the "Big Indian rock," which is ninety-two feet long, forty-two feet wide, and twenty-two feet in height above the water, is a well represented South American Llama which may indicate for this part of the sculpture either great antiquity, and the existence of that animal here, or a recent carving by some person who had seen it, or representations of it.

ETHNICAL PERIODS. By LEWIS H. MORGAN, of Rochester, N. Y.

THE Ethnical Periods, which, with their definitions, I wish to submit to your consideration, rest on the assumption that mankind commenced their career at the bottom of the scale, and worked their way up from savagery to civilization through the slow accumulations of experimental knowledge.

The discussion of the several classes of facts relating to this proposition will be facilitated by the establishment of a certain number of ethnical periods; each representing a distinct condition of society and distinguishable by a cultus peculiar to itself. Such a division of the great periods of savagery and of barbarism is desirable, if proper grounds for their definition are ascertainable.

The ages of *Stone*, *Bronze* and *Iron*, introduced by Danish archæologists, have been extremely useful for their purpose, and will remain so for the classification of objects of ancient art; but the progress of knowledge has rendered more definite subdivisions necessary, as well as an increase of their number. The use of stone implements commenced far back in savagery; and, after traversing the remainder of that period and the larger portion of that of barbarism, were not entirely laid aside with the introduction of tools of iron. Whilst the invention of the process of smelting iron ore created an ethnical epoch, this could scarcely have resulted from the production of bronze; and since the period of stone implements overlaps those of bronze and iron, and since that of bronze overlaps that of iron, they are not capable of a circumscription that would leave each independent and distinct.

It is probable that the successive arts of subsistence, which came in at long intervals apart, will ultimately afford the most satisfactory bases for these divisions, from the great influence they must have exercised upon the condition of mankind. But investigation has not been carried far enough in this direction to yield the necessary information. With our present knowledge the main result can be attained by selecting such an invention or discovery as affords a sufficient test of progress to characterize the commencement of a particular period, each new period terminating that of its predecessor. Even though accepted as provisional these ethnical periods will be found both convenient and useful. Each of those about to be proposed will be found to cover a distinct cultus, and to represent a particular mode of life.

Leaving the period of savagery, with its limited and peculiar arts to stand undivided, although longer in duration than the subsequent periods of barbarism and civilization together, the period of barbarism divides naturally into three sub-periods, which will be called, respectively, the Opening, the Middle, and the Closing period of barbarism; and the condition of society in each, respectively, will be distinguished as the Lower, the Middle, and the Upper status of barbarism.

1. Status of savagery.

In order to define these periods it is necessary to find tests of progress sufficiently definite and influential to work a transition from one state or condition into that next succeeding. The period of savagery commences with the infancy of the human race. All

things considered, the invention or practice of the art of pottery is probably the most effective test which can be selected to fix the boundary line between savagery and barbarism. The line of separation between the two conditions is necessarily arbitrary. It is a question of the degree of progress, the material object being to define conditions essentially different. Pottery implies an amount of development sufficient to indicate the close of savagery in the principal tribes of mankind, and the commencement of an improved condition. Since the manufacture of pottery is less expressive than the use of domestic animals, the use of iron, or the use of a phonetic alphabet, employed to mark the commencement of other ethnical periods, the reasons for its adoption should be stated. The use of pottery presupposes village life, and considerable progress in the simple arts. Flint and stone implements are older than pottery, remains of the former having been found in ancient repositories, in numerous instances, unaccompanied by the latter. A succession of inventions of greater need and adapted to a lower condition must have occurred before the want of pottery would be felt. The commencement of village life, with some degree of control over subsistence, wooden vessels and utensils, finger weaving with filaments of bark, basket making, and the bow and arrow, are found to make their appearance before the art of pottery. The Village Indians, who were in the Middle status of barbarism, such as the Zunians, the Aztecs and the Cholulans, manufactured pottery in great quantities and in many forms of considerable excellence; the partially Village Indians, who were in the Lower status of barbarism, such as the Iroquois, the Choctas and the Cherokees, made it in smaller quantities and in a limited number of forms; but the Non-horticultural Indians, who were in the Status of savagery, such as the Athapascans and the tribes of the Northwest Coast, were in general ignorant of its use.[1] In Lubbock's

[1] Mr. Edward B. Tylor observes that Goquet "first propounded, in the last century, the notion that the way in which pottery came to be made, was that people daubed such combustible vessels as these with clay, to protect them from fire, till they found that clay alone would answer the purpose, and thus the art of pottery came into the world." Goquet quotes from Capt. Gonneville, who, visiting the Indians near the east coast of South America, in 1503, who found their household utensils of wood, even their baking pots plastered over with clay, a good finger thick, which prevented the fire from burning them (Early History of Mankind, p. 273). The first vessels of pottery among the Aborigines of the United States, seem to have been made in willow or osier baskets used as moulds and afterwards burned off. Squier and Davis found evidence of this in the pottery of the Mound-builders and Mr. Rau the same. Vide Smithsonian Report, 1866, p. 352.

"Prehistoric Times," and in Tylor's "Early History of Mankind," the particulars respecting this art, and the extent of its distribution have been collected with remarkable breadth of research. It was unknown in Polynesia, with the exception of the Tongans and Fijians who were partly within and partly without its circumscription. It was unknown in Australia, in the Valley of the Columbia and in the Hudson's Bay Territory. Mr. Tylor remarks that "the art of weaving was unknown in most of the Islands away from Asia," and that "in most of the South Sea Islands there was no knowledge of pottery.[2] The Rev. Lorimer Fison, an English missionary resident in Australia, informed the author in answer to inquiries that the "Australians had no woven fabrics," and "no pottery," and "that they were without the bow and arrow," which last fact is also true, in general, of the Polynesians. The introduction of the ceramic art produced a new epoch in human progress in the direction of an improved living and increased domestic conveniences, while flint and stone implements, which came in earlier and required long periods of time to develop all their uses, gave the canoe, wooden vessels and utensils, and ultimately timber and plank in house architecture,[3] pottery gave a durable vessel for boiling food, which before that time had been rudely accomplished in baskets coated with clay, and in ground cavities lined with skin, the boiling being effected with heated stones.[4]

It may be remarked further that the experience of mankind, through savagery and barbarism, has run in nearly uniform channels; human necessities in similar conditions having been substantially the same, and the operations of the mental principle having been uniform in virtue of the specific identity of the brain in all the races of mankind. This, however, is but a part of the explanation. The germs of the principal institutions of mankind, and of the principal arts of life, were developed whilst man was still a savage. To a very great extent the experience of the subsequent periods of barbarism and of civilization has been expended in the further development of these original conceptions.

[2] Early History of Mankind p. 181. Lubbock's Prehistoric Times, pp. 437, 441, 462, 427, 538, 542.

[3] Lewis and Clarke (1805) found plank in use in houses among the Tribes on the Columbia River.—Travels, Longman's Ed., 1814, p, 503. Mr. John Keast Lord found "cedar plank chipped from the solid tree with chisels and hatchets made of stone" in Indian houses on Vancouver's Island. Naturalist in British Columbia, 1, 169.

[4] Tylor's Early History of Mankind, p. 265, et seq.

While it is difficult to find a single test of progress sufficient to meet every case, and to fix a clear boundary line between savagery and barbarism, because of the modifying influences of physical causes, the art of pottery is perhaps the most satisfactory which can be adopted. The distinctness of the two conditions, has long been recognized, but no test of progress out of the first and into the second has been brought forward. All such tribes, therefore, as never attained to the art of pottery will be classified as savages. Among existing tribes it leaves in a state of savagery the Australians, the body of the Polynesians, and a portion of the American Aborigines. It will be sufficient to give one or more exemplifications of each status.

II. Lower status of barbarism.

It commences, as before stated, with the introduction of the manufacture of pottery, whether by original invention or adoption. In order to fix its termination, and with that the commencement of the Middle status, a test of progress still more advanced must be found. Here, again, a difficulty is encountered in the unequal endowments of the two hemispheres; but it may be met by the adoption of equivalents. In the Eastern hemisphere the domestication of animals; and in the Western the cultivation of maize and plants by irrigation, together with the use of adobe-brick and stone in house architecture, have been selected as sufficient tests of progress out of the Lower, and into the Middle status of barbarism. It leaves in the Lower status of barbarism for example, the American Aborigines of the United States east of the Missouri River, and the tribes of Asia and Europe who practised the art of pottery but were without domestic animals.

III. Middle status of barbarism.

It commences, as stated, with the domestication of animals in the Eastern hemisphere: and in the Western with cultivation by irrigation and with the use of adobe-brick and stone in house architecture. To mark its termination and the commencement of the Upper status, the invention of the process of smelting iron ore has been selected. The production of iron was preëminently sufficient to create an ethnical epoch. It places in the Middle status, for example, the Village Indians of New and Old Mexico, Central America and Peru.

IV. UPPER STATUS OF BARBARISM.

It commences, as stated, with the manufacture and use of iron. The invention of a phonetic alphabet, with the use of writing in literary composition, has been chosen to fix the boundary line between this status and civilization. As an equivalent, hieroglyphical writing upon stone may be admitted. It leaves in the Upper status of barbarism, for example, the Grecian tribes of the Homeric age, the Italian tribes shortly before the founding of Rome, and the Germanic tribes of the time of Cæsar.

V. STATUS OF CIVILIZATION.

It commences, as stated, with the creation of literary records through the use of a phonetic alphabet, and divides into ancient and modern.

Recapitulated, these several ethnical periods are defined and circumscribed as follows.

	PERIODS.		CONDITIONS.
I.	Period of Savagery.	I.	Status of Savagery.
II.	Opening Period of Barbarism.	II.	Lower Status of Barbarism.
III.	Middle Period of Barbarism.	III.	Middle Status of Barbarism.
IV.	Closing Period of Barbarism.	IV.	Upper Status of Barbarism.
V.	Period of Civilization.	V.	Status of Civilization.

I.	Status of Savagery.	From the infancy of the human race to the invention of pottery.
II.	Lower Status of Barbarism.	From the use of Pottery to the Domestication of Animals in the Eastern Hemisphere: and in the Western to the cultivation of Maize and Plants by irrigation, with the use of adobes and dressed stone in houses.
III.	Middle Status of Barbarism.	From the Domestication of animals, etc., to the Manufacture and use of Iron.
IV.	Upper Status of Barbarism.	From the use of Iron to the invention of a Phonetic Alphabet, with the use of writing in Literary Composition.
V.	Status of Civilization.	From the use of Alphabetic Writing in the Production of Literary Records to the Present Time. It divides into Ancient and Modern.

Each of these periods has a distinct and well-marked cultus, and exhibits a mode of life more or less special and peculiar to itself. The time is at hand, in the progress of ethnology, when it has become possible to treat human society according to its conditions of relative advancement, and to make each condition a subject of independent study and discussion. It seems now to be imperative that this or some other division into definite periods should be made, that the tribes and nations of mankind, whose institutions are pure and homogeneous, may be classified according to the degree of their progress; and that the state of development characteristic of each period may be separately known. When the elements of each condition are thoroughly understood it may become possible to articulate, in a connected series, the institutions, inventions and discoveries belonging to each respectively; and to deduce therefrom the successive steps of human progress from the bottom of the scale up to the highest point of present attainment. It does not affect the main results that tribes and nations on the same continent are in all these conditions at the same point of time; since for our purpose the *conditions* of each is the material fact, the *time* being immaterial.

There is another advantage of no inconsiderable importance that will be gained by means of definite ethnical periods; namely, the direction of special investigation to those tribes and nations which afford the best exemplification of each status, with a view of making the condition of each both standard and illustrative. The experience of the tribes and families of mankind has been very unequal. Some have been left undisturbed in geographical isolation to work out the problems of progress by original mental effort; and have, consequently, retained their arts and institutions pure and homogeneous; whilst those of other tribes and nations have been adulterated by external influence and intermixture. Thus, while Africa is an ethnical chaos of savagery and barbarism, Australia and Polynesia are in savagery, pure and simple, with the arts and institutions belonging to this condition. In like manner the Red Race of America, unlike any other existing family, exemplified the condition of mankind in three successive ethnical periods; namely, the Period of Savagery, and the Opening and the Middle period of Barbarism. In the undisturbed possession of a great continent, of common descent, and with homogeneous institutions, they illustrated, when discovered, the cultus of

each, and especially of the Lower and of the Middle status of barbarism, more completely and elaborately than any other portion of mankind. The spectacle of the same race, with the same original language and institutions in the successive stages of advancement represented by three great ethnical periods, is without a parallel in human history. The far Northern Indians, as before stated, were in the Status of savagery, but near its end; the partially Village Indians east of the Missouri were in the Lower status of barbarism, and the Village Indians of North and South America, including the Mound Builders, were in the Middle status of barbarism. Such an opportunity to recover full and minute information of the course of human experience and progress in these successive conditions of society has not been offered within the historical period, and, it must be added, it has been but indifferently improved. Our greatest deficiencies relate to the last two periods named.

Differences in the culture of the same period in the Eastern and Western hemispheres undoubtedly existed in consequence of the unequal endowments of the continents; but in the main the condition of society must have been substantially similar in both in the corresponding status. The ancestors of the Grecian, Roman and German tribes passed through the experience of savagery before they attained to the Lower status of barbarism, through the experience of the latter before they attained to the Middle status, and through the experience of the last before they reached the Upper status, in the midst of which the light of history fell upon them. Their differentiation from the undistinguished mass of barbarians did not occur, probably, earlier than the commencement of the Middle period of barbarism. The experience of these tribes, in these successive stages of progress, has been lost, with the exception of so much as is represented by the institutions, inventions and discoveries which they brought with them as memorials of these conditions, and which they held in their custody when they first came under historical notice. The Grecian and Latin tribes, immediately before their civilization, afford the highest exemplification of the Upper status of barbarism. Their institutions were also pure and homogeneous, and their experience stands directly connected with the final achievement of civilization.

Commencing with the Australians and Polynesians, following with the American Aborigines, and concluding with the German,

Roman and Grecian tribes, who afford the highest exemplification respectively of the five great stages of human progress, the sum of their united experiences may be supposed fairly to represent that of the human family, from the middle part of the period of savagery to the end of ancient civilization. Consequently the Aryan nations will find the type of the condition of their remote ancestors, when in Savagery, in that of the Australians and Polynesians, when in the Lower status of barbarism, in that of the partially Village Indians of America; and when in the Middle status in that of the Village Indians. So essentially identical are the arts, institutions, and mode of life in the same status upon all the continents, that the archaic form of the principal domestic institutions of the Greeks and Romans must even now be sought in the corresponding institutions of the American Aborigines. This fact forms a part of the accumulating evidence tending to show that the principal institutions of mankind have been developed from a few primary germs of thought; and that the course and manner of their development were predetermined, as well as restricted within narrow limits of divergence, by the natural logic of the human mind, and the necessary limitations of its powers. Progress, therefore, has been substantially the same in kind in tribes and nations inhabiting disconnected areas, while in the same status, with deviations from uniformity produced by special causes. In studying the condition of mankind in these several ethnical periods we are dealing, substantially, with the ancient history and condition of our own remote ancestors.

ARTS OF SUBSISTENCE. By LEWIS H. MORGAN, of Rochester, N. Y.

THE same great fact that mankind commenced their career at the bottom of the scale and worked their way up to civilization, through growth in knowledge, is revealed in an expressive manner by their successive arts of subsistence. Upon their success in multiplying the sources and increasing the amount of food the whole question of human supremacy on the earth depended. Man-

kind are the only beings who may be said to have gained an absolute control over the production of food. Their advancement has been identified substantially with the growth of that control, because at the outset they did not possess it above other animals. A knowledge of the art of subsisting themselves was essential to the preservation of the species, and not less difficult, certainly, in the primitive period than at the present time. Without enlarging the basis of that subsistence mankind could not have propagated themselves into other areas not possessing the same kinds of food, and ultimately over the whole surface of the earth; and lastly, without obtaining an absolute control over both its variety and amount they could not have multiplied into populous nations. It is accordingly probable that the great epochs of human progress have been identified, more or less directly, with the enlargement of the sources of subsistence.

We are able to distinguish five of these sources of human food, created by what may be called as many successive arts, one superadded to the other, and brought out at long separated intervals of time. The first two originated in the period of savagery, and the last three in the period of barbarism. They are the following, stated in the order of their appearance.

I.—Natural Subsistence upon Fruits and Roots in a Restricted Habitat.

This form goes back to the infancy of the human race, and assumes its developments from one primitive stock. It carries with it the further assumption that this stock was then possessed of a matured and efficient art of subsistence which had brought them thus far in their habitat and prepared them to enter upon a wider career. This primitive mode of sustentation, simple though it may have been, had an intelligent growth as well as a history, which ran back into the experience of the lower progenitors of the human race, if the doctrine of evolution from lower forms is accepted. In any event so essential is this wonderful art to the preservation of every species that it must have been constantly attended with the element of certainty. Animal food, in all probability, entered from a very early period into human consumption; but whether it was actively sought when mankind were essentially frugivorous in practice, though omnivorous in structural organization, must re-

main a matter of conjecture. This mode of sustenance belongs to the strictly primitive period.

II.—Fish Subsistence.

In fish must be recognized the first kind of artificial food, because it was not fully available without cooking by means of fire. It seems probable, therefore, that this new species of food came in subsequently to a knowledge of the use of fire, first utilized, not unlikely, for this purpose. Upon a fish subsistence mankind were enabled to leave their original habitat and propagate themselves over wider areas. Their spread over the greater part of the earth's surface, whilst in the savage state, of which fact there is abundant evidence in the remains of flint and stone implements of the Status of savagery found upon all the continents, can only be explained on the hypothesis of their migration upon a fish subsistence, which was universal in distribution, unlimited in supply, and the only kind of food at all times attainable. The cereals were still unknown, if in fact they existed, and the hunt for game was too precarious ever to have formed an exclusive means of human support. Upon this species of food mankind became independent of climate and of locality; and, by following the shores of the seas and lakes, and the courses of the rivers, could spread themselves over the greater portion of the earth's surface. But upon fruits and spontaneous subsistence this would have been impossible.

Between the introduction of fish subsistence, followed by the wide migrations named, and the acquisition of farinaceous food through cultivation, the interval of time was immense in duration. It covers nearly if not the entire period of savagery. But during this interval there was an important increase in the variety and amount of food in various ways; such, for example, as the use of bread roots cooked in ground ovens, and in the permanent addition of game through improved weapons, and especially through the invention of the bow and arrow. This remarkable invention, which came in after the spear and war club and gave the first deadly weapon for the hunt, appeared late in savagery. It must have given a powerful upward influence to ancient society, standing in the same relation to the period of savagery, as the iron sword to the period of barbarism, and fire arms to the period of civilization. If the period of savagery should be divided into three sub-periods, as that of barbarism has been, natural subsis-

tence would belong to the Lower, fish subsistence to the Middle, and game subsistence to the Upper status of savagery. When fish became superadded to natural fruits, and later, when bread roots and game became superadded to both, the condition of mankind in each case was necessarily much improved. These were the main sources of human maintenance throughout the prolonged period of savagery.

From the precarious nature of all these sources of human food, outside of the great fish areas, cannibalism became the dire resort of savage man in the extremity of hunger. This practice, the ancient universality of which in the period of savagery is being gradually demonstrated, testifies significantly to the undeveloped condition of the mental and moral faculties of the human mind in that early period.

III.—Farinaceous Subsistence through Cultivation.

Following the course of human progress in developing the successive arts of subsistence, we now leave the Status of savagery and enter the Lower status of barbarism. Farinaceous food, through the cultivation of cereals and plants, was unknown in the Western hemisphere except among the tribes who had emerged from savagery; and it seems to have been unknown in the Eastern hemisphere until after the tribes of Asia and Europe had passed through the Lower, and had drawn near to the close of the Middle status of barbarism. It gives us the singular fact that the American Indian tribes, in the Lower status of barbarism, were in possession of horticulture and of farinaceous food one entire ethnical period earlier than the inhabitants of the Eastern hemisphere. It was a consequence of the unequal endowments of the two hemispheres, the Eastern possessing all the animals adapted to domestication, save one, and a majority of the cereals; while the Western in maize, its one only cereal fit for cultivation, had the best of all of them with which to inaugurate the use of farinaceous food. It tended to prolong the duration of the Opening period of barbarism in the former, and to shorten it in the latter; with the advantage of condition in this period in favor of the American aborigines. But when the most advanced tribes in the Eastern hemisphere, at the commencement of the Middle period of barbarism, had domesticated animals which gave them a permanent meat and milk subsistence, their condition, without a knowl-

edge of the cereals, was much superior to that of the American aborigines in the corresponding period with the possession of maize and plants, but without domestic animals. The differentiation of the Semitic and Aryan families from the mass of barbarians seems to have commenced with the domestication of animals.

That the discovery and cultivation of the cereals by the Aryan family was subsequent to the domestication of animals is shown by the fact, that there are common terms for these animals in the several dialects of the Aryan language, and no common terms for the cereals or cultivated plants. Mommsen, after showing that the domestic animals have the same names in the Sanskrit, Greek and Latin, which Max Müller afterwards extended to the remaining Aryan dialects,[1] thus proving that they were known and presumptively domesticated before the separation of these nations from each other, proceeds as follows: "On the other hand, we have as yet no certain proofs of the existence of agriculture at this period. Language rather favors the negative view. Of the Latin Greek names of grain, none occur in the Sanskrit with the single exception of *Ζεά* which philologically represents the Sanskrit *Yavas*, but denotes in Indian, barley, in Greek, spelt. It must, indeed, be granted that this diversity in the names of cultivated plants, which so strongly contrasts with the essential agreement in the appellations of domestic animals, does not absolutely preclude the supposition of a common original agriculture. The cultivation of rice among the Indians, that of wheat and spelt among the Greeks, and that of rye and oats among the Germans and Celts, may all be traceable to a common system of original tillage."[2] This last conclusion is forced. Horticulture preceded field culture, as the garden (*hortos*) preceded the field (*ager*); and although the latter implies boundaries, the former signifies directly an "enclosed space." Tillage, however, must have been older than the enclosed garden; the natural order being, first, tillage of patches of open alluvial land, second, of enclosed spaces or gardens, and third, of the field, by means of the plow drawn by animal power. Whether the cultivation of such plants as the pea, bean, turnip, parsnip, beet, squash, and melon, one or more of them, preceded the cultivation of the cereals, we have, at present, no means of knowing. Some of these

[1] Chips from a German Workshop. Comp. Table II, p. 42.
[2] History of Rome, Scribner's Ed., Vol. 1, p. 38.

have common terms in Greek and Latin; but I am assured by our eminent philologist, Prof. W. D. Whitney, that neither of them has a common term in Greek or Latin and Sanskrit.

Horticulture was practised generally by the American Aborigines in the Lower status of barbarism, while it seems to have been entirely unknown among Asiatic and European tribes in the corresponding status. It commenced in the Eastern hemisphere, as now seems probable, near the close of the Middle period, and originated more in the necessities of the domestic animals than in the necessities of mankind. In the Western it commenced with maize. A new era in human progress was thereby created, although not synchronous in the two hemispheres, of immense importance in its influence upon the destiny of mankind. There are reasons for believing that it required ages of time to establish the art of cultivation, and render farinaceous food a principal reliance. It came in as a superadded subsistence, as well as independently in the two hemispheres. Since in America it led to localization and to village life, it tended to the substitution of farinaceous food, especially among the Village Indians, in the place of fish and game which ceased to be attainable, except in limited quantities, as the primary means of sustaining life. From the cereals and cultivated plants, mankind obtained their first impression of the possibility of an abundance of food.

The acquisition of farinaceous food in America, and of domestic animals in Asia and Europe, was the means of delivering the advanced tribes, thus provided, from the scourge of cannibalism, which, as elsewhere stated, there are reasons for believing, was universal throughout the period of savagery; practised habitually upon captured enemies, and in time of famine upon friends and kindred. Cannibalism in war, practised by war parties in the field, survived among the American aborigines not only in the Lower, but also in the Middle status of barbarism, as, for example, among the Iroquois and the Aztecs; but the general practice had disappeared. The great influence of a permanent increase of food in ameliorating the condition of mankind may be inferred from this among other considerations.

IV. Meat and Milk Subsistence.

The absence of animals adapted to domestication in the western

hemisphere, excepting the llama,[3] and the specific differences in the cereals of the two hemispheres exercised an important influence upon the relative advancement of their inhabitants. While the inequality of physical endowments was immaterial to mankind in the period of savagery, it made an essential difference with that portion who had attained to the Middle status of barbarism. A marked differentiation of the races in the two hemispheres must have commenced as soon as this condition was attained. In the Eastern a permanent meat and milk subsistence, through the domestication of animals, was superadded to the previous food of the race; while in the Western meat was restricted to the precarious supplies of game among the tribes in savagery, and in the Lower status of barbarism, and reduced to an inconsiderable amount of animal food among the tribes in the Middle status. This limitation upon an essential species of human food was unfavorable to the physical and mental vigor of the Village Indians, and, doubtless, sufficiently explains the inferior size of the brain among them in comparison with that of Indians in the Lower status of barbarism.

The domestication of animals, followed in time by their production in flocks and herds, superadded a new and most important source of human food; but restricted to the Eastern hemisphere. It enabled the thrifty and industrious to secure for themselves a permanent supply of animal food, including milk, throughout the year, the healthful and invigorating influence of which upon the race, and especially upon children while in the growing state, was undoubtedly remarkable. It is at least supposable that the Aryan and Semitic families owe their preëminent endowments to the great scale upon which, as far back as our knowledge extends, they have identified themselves with the maintenance in numbers of the domestic animals; and incorporated them, flesh, milk, and muscle, into their plan of life. No other family of mankind has done this to an equal extent;[4] and of the two, the Aryan to a greater degree than the Semitic.

[3] The early Spanish writers speak of a "dumb dog" found domesticated in the West India Islands, and also in Mexico and Central America (see figure of Aztec dog in Clavigero's History of Mexico, Vol, 1, Pl. III). I have seen no identification of the animal. They also speak of poultry as well as turkeys on the continent. The aborig ines had domesticated the turkey and the Nahuatlac tribes some species of wild fowl.

[4] We learn from the Iliad that the Greeks milked their sheep as well as their cows and goats;—

— ὥστ' ὄϊες πολυπάμονος 'ανδρὸς 'εν αὐλῇ
μυρίαι ἑστήκασιν ἀμελγόμεναι γάλα λευκὸν

Iliad, iv, 433.

The domestication of animals gradually introduced a new mode of life, the pastoral, which, in turn, must have concentrated these stocks upon the plains of the Euphrates and of India, and upon the steppes of Asia; on the confines of one or the other of which their domestication was probably first accomplished. To these areas their oldest traditions and their histories alike refer them. They were thus drawn to regions which, so far from being the cradle lands of the human race, were areas they would not have occupied as savages, or as barbarians in the Lower status of barbarism, to whom forest areas were natural homes. After entering the pastoral condition, and becoming habituated to pastoral life it must have been impossible for either of these families to reënter the forest areas of Western Asia and of Europe, with their flocks and herds, without first learning to cultivate some of the cereals with which to subsist the latter at a distance from the grass plains. It seems extremely probable, therefore, that the cultivation of the cereals originated in the necessities of the domestic animals, and in connection with these western migrations; and that the use of farinaceous food by these tribes was a consequence of the knowledge thus acquired.

In the Western hemisphere the aborigines were enabled to advance generally into the Lower status of barbarism, and a portion of them into the Middle status, without domestic animals, excepting the llama in Peru, and upon a single cereal, maize, with the adjuncts of the bean, squash, and tobacco, and in some areas, cocoa, cotton and pepper. But maize, from its growth in the hill which favored direct cultivation, from its usableness in the green as well as in the ripe state, and from its abundant yield and nutritive properties, was a richer endowment in aid of early human progress than all other cereals put together. It serves to explain the remarkable progress the American aborigines had made without the domestic animals; the Peruvians having produced bronze, which stands next and quite near, in the order of time, to the process of smelting iron ore. The supply of game was necessarily precarious, and especially so with the Village Indians who led the advance in progress.

V. Unlimited Subsistence through Field Agriculture.

The domestic animals supplemented human muscle with animal power, which contributed a new factor of the highest value for

human advancement. In course of time the production of iron gave the plow with an iron point, together with the iron spade and axe. Out of these, and the previous horticulture which taught the theory of cultivation, came field agriculture, and with it, for the first time in human experience, unlimited subsistence. It may be regarded as a newly gained art because of the use of the plow drawn by animal power, which was to extend so largely the area of cultivation. Now for the first time the thought entered the human mind of reducing the forest and bringing wide fields under cultivation, rendered possible by the possession of iron tools.[5] Moreover, dense populations in limited areas now became possible. Prior to field agriculture it is not probable that half a million people were developed and held together under one government in any part of the earth. If exceptions occurred, they must have resulted from pastoral life on the plains, or from horticulture improved by irrigation, under peculiar and exceptional conditions. With field agriculture came the means of sustaining dense populations, and of establishing nations in fixed areas with some degree of permanence.

These several arts of subsistence, introduced with the growth of human experience at widely separated intervals of time, are in themselves not only conclusive evidence of a graduated human progress, but they indicate very plainly a progressive development from a low scale of being—lower in fact than the most penetrating scrutiny can fully realize.

Indian Burial Mounds and Shellheaps near Pensacola, Florida. By G. M. Sternberg, Surgeon U. S. Army.

Having recently devoted some time to the exploration of two Indian burial mounds in the vicinity of Pensacola, Florida, I propose to put upon record the results of my explorations as a contribution to American Archæology.

[5] Inque dies magis in montem succedere silvas
Cogebant, infraque locum concedere cultis;
Prata, lacus, rivos, segetes, vinetaque laeta
Collibus et campis ut haberent.
Lucr. De Re. Nat. V, 1369.

One of these mounds is in Alabama, and is situated upon the extremity of a peninsula formed by two arms of the Perdido Bay. This bay and the river of the same name form the boundary between the states of Alabama and Florida.

I shall call this the Bear Point Mound as the peninsula upon which it is situated is known by this name. The second mound is in Florida, about fifty miles east of Bear Point, and is also on a peninsula; formed by Pensacola Bay on the one side and Santa Rosa Sound on the other. There is reason to suppose, as I shall presently show, that these mounds were built by different, but contemporaneous, tribes of Indians, and it is quite probable that these tribes were hostile to each other. This I infer from the fact that their villages, the locations of which are shown by extensive shell-heaps (kjökkenmöddings), are situated upon peninsulas, and so located that hostile parties from either one would be unable to approach the other except in canoes, or by an exceedingly difficult and circuitous land route. Also, from the fact that the sea-coast and bays between these two villages present no evidence of occupation by the Indians, except here and there a few scattered shell-heaps of small size, marking the site of the wigwam of some hardy brave, who obtained a subsistence from the debatable ground between the hostile towns, with less labor, though at greater risk, than his less venturesome companions. On the Florida side of the Perdido Bay, six miles distant from Bear Point, there are extensive shell-heaps marking the location of another village, upon a peninsula known as Anerierty's Point. This location was probably occupied by the same tribe as the opposite point, and, no doubt, communication was kept up between the two villages by means of canoes. As there is no burial mound upon this point, it may be that, owing to the more exposed situation of this village, the sacred remains of the dead were transported across the bay for sepulture in the Bear Point mound.

The shell-heaps at both of these places are composed almost entirely of oyster shells. In this respect they differ from the Santa Rosa Sound locality, where the shells are mainly those of a small round species of clam (?). The area covered by these shell-heaps I am unable to estimate with any precision, as a great portion of it is covered with live-oak timber interspersed with a dense growth of underbrush. In all the localities mentioned however, the land has been cleared to some extent for the purpose

of cultivation, as these "shell-banks" are favorite locations for the raising of corn, watermelons and fruit trees (orange, fig, and peach). The cleared land covered with shells at Bear Point I should estimate at 60 acres; at Anerierty's Point, at 100 acres; and in the vicinity of the Santa Rosa mound, at 150 acres. The extent of the shell-heaps is, however, very much greater than this. The shells are scattered over the surface in irregular heaps, the contents of which vary from a few bushels to thousands of bushels.

Those on the surface are more or less softened and broken by the action of the elements and the plow. But upon digging down a little way, to where they are undisturbed, they are found to be nearly as fresh looking as if they had but recently been thrown out from a modern oyster saloon. The size and shape of the shells show that the epicures among our aboriginal predecessors feasted upon oysters as large and probably as luscious as any that are now found in the New Orleans or Mobile markets. Whether they obtained the immense supplies, which they consumed, from the waters of the bay, without any further trouble or care than that involved in the labor of gathering them, we cannot at present decide. But I think it not improbable that they may have cultivated them, as is at present practised, or at least that the mode and time of procuring this, their staple article of diet, was regulated by law or custom. This view is sustained by the fact that the shell-heaps contain only the shells of large and well-developed oysters, such as would be marketable at the present day.

The Santa Rosa Sound Indians were not so particular as is shown by the presence, in their "kitchen middens" of the shells of various species of univalve and bivalve mollusks, such as are still found in the waters of the sound.

Oysters are not at present found in the Perdido Bay in any quantity, owing, it is said, to the waters being too fresh for them to live in it.

The age of these shell-heaps can only be estimated in a rough manner from the appearance and position of the shells. As has already been stated, those on the surface bear marks of age, while those deeper down look quite fresh. In many places the decayed stumps of live-oak trees, of from two to three feet diameter, are found in situ above the shells.

That the Bear Point Indians were successful fishermen is clearly

shown by numerous fish bones which are found scattered through their heaps of kitchen-refuse.

That they did not depend to any considerable extent upon the chase for their subsistence is proved by the comparative scarcity of the bones of animals. The Santa Rosa Sound Indians, on the contrary, were great hunters, and venison was a staple article in their bill of fare. They also made great use of the skins of animals which they doubtless dressed and sewed together for clothing. This is shown by the great number of bone awls, which are found scattered through their "kitchen-middens."

At Bear Point none of these tools are found. Their absence, taken in connection with other circumstances which I shall presently point out, I take to be an evidence of a more advanced state of civilization. Instead of being rude hunters whose only dress was the skins of the animals upon whose flesh they subsisted, these Indians devoted themselves to agriculture, and doubtless had learned the art of fabricating clothing from grasses and vegetable fibre of different kinds.[1]

To sew such fabrics they would require a slender needle that would pass entirely through the material, carrying the thread with it. Such needles, probably made of slender fish bones, would be very perishable, and we could hardly expect to find them at the present day.

The great skill attained by these Indians in the ceramic art, the large number of clay vessels required in their domestic operations, and the fact that they were not hunters, all show that they must have been an agricultural people, dwelling in fixed habitations, and clothing themselves in some fabric of their own manufacture.[2]

It is impossible to believe that naked savages whose only diet

[1] Mantles made of the inner bark of trees, and also of a kind of grass not unlike flax, were seen by the early explorers of Florida (Irving, "Conquest of Florida," p. 230).

Mantles fabricated from coarse threads of the bark of trees and nettles are also mentioned (loc. cit. p. 317).

[2] The historians of De Soto's expedition (*vide* Irving's "Conquest of Florida") speak frequently of Indian villages containing from 50 to 600 dwellings, substantially constructed of wood (loc. cit. p. 98, 104, 111, 184, 284). The fortified town of Mauvila was in Alabama, probably in the vicinity of Choctaw Bluff, Clark Co., and is stated to have been but seven days' journey from Pensacola Bay (p. 284). It is described as containing eighty houses, capable of lodging from 500 to 1,500 persons, and as being fortified by a high wall formed of tree trunks driven into the ground, flattened with a mortar of clay and straw.

Frequent mention is also made of extensive fields of Indian corn, beans, pumpkins, and other vegetables.

was fish and oysters would manufacture pottery of such excellent design and finish, and so artistically ornamented, as is that which I have obtained from their burial mound, and the fragments of which are scattered in the greatest abundance over the site of their village.[3]

The pottery was not all, however, of such fine quality. Articles were made for every day use, in the manufacture of which utility alone was kept in view, there being no attempt at ornamentation, or only such as required but little time and skill.

The present owners of the land have occasionally picked up, while cultivating the "shell banks," clay images of the heads of birds and animals, and a single specimen of the "human face divine" as conceived and modelled by an aboriginal American sculptor.

Whether these images had any special significance I am unable to say. Some of them seem to have formed the handles of earthen vessels, and others were, in my opinion, nothing more than toys made for the amusement of Indian babies, or children of larger growth. One in the shape of a squirrel's head is evidently a rattlebox. It is hollow and contains fragments of something which rattle when it is shaken. I imagine that the absence of the ears, and the generally dilapidated condition of this specimen, are due to its having been mouthed by some drooling Indian baby while teething.

A similar rattlebox in the shape of an owl's head was found, by some children, at Anerierty's Point, but was destroyed by being crushed between two stones, for the purpose, as they said, of getting at "the brains."

The said "brains" were found to be small lumps of clay, designed evidently as "rattle brains."

No flint weapons are found in the shell-heaps, but I have obtained a few of fine form and finish from the mound. These must have been obtained from a distance, by barter with other tribes, as there is no flint in the vicinity. The difficulty of obtaining this standard material for the formation of arrow and spear-heads, probably made it necessary for these Indians to employ something more readily obtained and nearer at hand for common use, and

[3] In one instance the army of De Soto marched for two leagues through fields of corn (p. 138). Again, in the province of Appalachee, subsistence was obtained for 1,500 persons for five months (p. 193). Five hundred measures of meal made from toasted corn were obtained from a single house (p. 213).

the few flints in their possession would naturally be considered of great value. I think it probable, therefore, that those found in the mound mark the burial place of chiefs or distinguished warriors. It is likely that their arrows were commonly made of wood or reeds, hardened at the point by burning, or tipped with sharp fish bones.[4]

Fragments of red hematite found in the mound and scattered over the shell-heaps were doubtless used to furnish a red pigment for decorating the person, according to the almost universal custom among the American Indians.

That personal ornamentation was not neglected is further shown by a string of large beads cut out of conch shell, which was taken from the mound. Other shell ornaments in the shape of perforated disks, etc., have been picked up on the shell-heaps. Blue glass beads have also been found, which are doubtless of European manufacture. These, and an iron spike which I myself took from the mound, prove conclusively that the Indians still occupied this location after the discovery of the country by the whites. Two other fragments of iron have also been taken from this mound where they were associated with the remains of the dead in the same way as were the arrow-heads and other articles found. It is evident that they were buried as articles of great value, probably belonging to the individual with whose remains they were associated, and consequently that intercourse with the whites had not yet been sufficiently established to make iron a common article of use among the builders of the mound.

The Indians have not occupied this locality within the recollection of the oldest settlers, nor do the local traditions, which extend back for a period of more than eighty years, give any account of them. My own opinion is that this village was a frontier settlement of the Natchez Indians.

The Bear Point burial mound, which I shall now proceed to describe, is especially interesting from the fact that its age is determined with a certain degree of accuracy by the iron spike to which reference has already been made, and by a single glass bead which I found in it. That the mound was erected by, and was the burial

[4] De Soto's historians mention in several places the use of arrows barbed with flint (Irving loc. cit. p. 191, 195, 225). But they also speak of arrows without barbs, and of others made of reeds "tipped with buckshorn wrought with four corners like a diamond, some with bones of fishes curiously fashioned, others with barbs of palm, and other hard woods."

place of, the people who lived in the village near by, is amply proved by the fact that the pottery taken from it is of the same kind and ornamented in like manner with that of which innumerable fragments are found scattered through the shell-heaps.

The mound is situated upon sloping ground, and has an altitude of from twelve to fifteen feet on the lower or western side, and of six to eight feet on the opposite side. It is nearly circular and has a diameter of about 100 feet.

There are several good sized trees growing upon it, and one, a live-oak, is more than two feet in diameter. The mound is built of yellow sand taken from the immediate vicinity; as is evident not only from its being of the same character as the surrounding soil, but from pits about its base from which sand has been removed for its construction.

Before visiting the mound I was informed that the Indians were buried in it, in an upright position, each one with a clay pot on his head. This idea was based upon some superficial explorations which had been made from time to time by curiosity hunters. Their excavations had indeed brought to light pots containing fragments of skulls, but not buried in the position they imagined. Very extensive explorations made at different times, by myself, have shown that only fragments of skulls and of the long bones of the body are to be found in the mound, and that these are commonly associated with earthen pots, sometimes whole, but more frequently broken fragments only. In some instances portions of the skull were placed in a pot, and the long bones were deposited in its immediate vicinity. Again, the pots would contain only sand, and fragments of bones would be found near them. The most successful "find" I made, was a whole nest of pots, to the number of half a dozen, all in a good state of preservation and buried with a fragment of skull, which I take, from its small size, to have been that of a female. Whether this female was thus distinguished above all others buried in the mound, by the number of pots deposited with her remains, because of her skill in the manufacture of such ware, or by reason of the unusual wealth of her sorrowing husband, must remain a matter of conjecture. I found, all together, fragments of skulls and thigh bones belonging to at least fifty individuals; but in no instance did I find anything like a complete skeleton. There were no vertebræ, no ribs, no pelvic bones, and none of the small bones of the hands

and feet. Two or three skulls, nearly perfect, were found, but they were so fragile that it was impossible to preserve them. In the majority of instances only fragments of the frontal and parietal bones were found; buried in pots, or in fragments of pots, too small to have ever contained a complete skull. The conclusion was irresistible that this was not a burial place for *the bodies* of deceased Indians, but that the bones had been gathered from some other locality for burial in this mound; or that cremation was practised before burial, and the fragments of bone not consumed by fire were gathered and deposited in the mound.

That the latter supposition is the correct one I deem probable, from the fact that in digging in the mound evidences of fire are found in numerous places, but without any regularity as to depth and position.

These evidences consist in strata of from one to four inches in thickness, in which the sand is of a dark color, and has mixed with it numerous small fragments of charcoal. My theory is, that the mound was built by gradual accretion in the following manner. That when a death occurred, a funeral pyre was erected on the mound, upon which the body was placed. That after the body was consumed, any fragments of bones remaining were gathered, placed in a pot and buried. And that the ashes and cinders were covered by a layer of sand brought from the immediate vicinity for that purpose. This view is further supported by the fact that only the shafts of the long bones are found, the expanded extremities, which would be most easily consumed, having disappeared. Also by the fact that no bones of children were found. Their bones being smaller, and containing a less proportion of earthy matter, would be entirely consumed.

I found in the mound several small pots which may be supposed to have been the property of children, and in one I found a toy arrow-point made of shell.

This I take to have been a mother's tribute to the memory of her little one, and the fact that no bones were found in its vicinity supports the supposition that the body was entirely consumed by the flames.

It may be, however, that the Indians were in the habit of preserving the remains of their friends above ground for a certain length of time, in caskets, or upon platforms elevated upon

poles or in trees, and that at stated periods they were taken to the mound, consumed with fire, and the fragments of bone buried in the manner already indicated.[4]

At the Santa Rosa mound the method of burial was different. Here I found the skeletons complete, and obtained nine well preserved skulls (Destined for the Army Medical Museum). The bodies were not, apparently, deposited upon any regular system, and I found no objects of interest associated with the remains. It may be that this was due to the fact that the skeletons found were those of warriors who had fallen in a battle in which they had sustained a defeat. This view is supported by the fact that they were all males, and that two of the skulls bore marks of antemortem injuries which must have been of a fatal character.[5]

It may be that a more complete exploration of this mound, which is considerably larger than that at Bear Point, would throw additional light upon the mode of life and peculiar customs of its builders. The skeletons found show that they were an athletic race, and one thigh bone which I have preserved measures nineteen inches in length.[6]

The skulls taken from this mound with a single exception belong to the type denominated *brachycephalic* and the jaws are prognathous. There is also in nearly all a remarkable want of symmetry in the posterior region of the skull; it being flattened, and having a projecting bulge to one side or the other. This is probably a deformity produced during childhood, either intentionally, or as a consequence of the practice adopted by the Indian mothers of strapping their infants to a board for safe keeping. The bones are well preserved in consequence of the mound having been constructed from peaty soil taken from the swamp in which the mound is built.

[4] We read in Irving (loc. cit.) that Juan Ortiz was placed on guard over an Indian cemetery which was situated in a lonely forest, and in which the bodies were preserved in wooden boxes (p. 64). In another place, that the chiefs and warriors were buried in a temple or mausoleum, in which the bodies were deposited in wooden boxes (p. 230).

[5] It is stated by Irving (loc. cit.) on the authority of the Spanish and Portugese narratives from which he obtained the facts detailed in his book; that a superstitious belief prevailed among the Florida Indians, that "those defeated in battle were infamous and accursed;" and, in another place, that the bodies of Indians fallen in battle were heaped up in a mound, unburied (p. 149).

[6] De Soto's historians make frequent mention of the gigantic size of some of the Florida Indians, and they are commonly spoken of as of good stature and well formed (Irving, loc. cit. pp. 31, 110, 125, 188). One young chief is mentioned as being taller than any Spaniard in the army (p. 256), and Tuscaloosa, the father of this young chief, is said to have been a foot and a half taller than any Indian in the army (p. 258).

The facts bearing upon the age of this mound, which my explorations have thus far developed, are the following.

The articles found in it and in the vicinity are all of Indian manufacture. These are, numerous fragments of pottery, more rude in design than those from the Bear Point locality; a large number of bone awls of different shapes and sizes; a single shell adze, or scraping tool. On the other hand, a tibia dug from the mound presents the appearance of having been affected during life by a disease which was unknown among the Indians prior to the arrival of the whites; one of the skulls has a hole through its vertex which looks wonderfully like a bullet hole; and one of the skulls taken from the mound differs from all the others in being *dolichocephalous*, and symmetrical in shape. This may be the skull of a white man or half breed.

The mound from which these skulls were obtained is located in a swamp about 500 yards in rear of the village, which was (as shown by the shell-heaps), directly on the margin of the sound.

In a commanding position near the centre of the village is another mound, higher than the burial mound, but having a much less diameter (about twenty feet high and sixty in diameter). A partial exploration of this revealed no bones or other objects of interest, except such as are found in the kitchen-middens in the neighborhood, which have evidently furnished the materials for its construction.

From its summit an extensive view is obtained of the Sound, of Santa Rosa Island, and of the Gulf of Mexico beyond. Its commanding position is shown by the fact that the confederates erected a battery upon it during the war, for the purpose of preventing light draught gun-boats from entering Pensacola harbor by way of Santa Rosa Sound.

This mound was probably erected as a lookout station, and may have had upon it the residence of the chief or head man of the village.[7]

We may imagine a crowd of astonished savages, painted and plumed, gathered upon its summit and looking over the Gulf at the approaching ships of Gomes Arias, who in 1540 came, by appointment,[8] to meet De Soto at the Bay of Achusi (Pensacola).

[7] De Soto found the Chief's dwelling built upon an artificial mound in several villages which he visited (Irving, loc. cit. p. 58 and 129).

[8] De Soto failed to keep the rendezvous appointed with Arias, for reasons of his own, (loc. cit. p. 283), and the latter after cruising about all summer in a vain attempt to rejoin his commander, was obliged, upon the approach of winter, to return to Havana.

From the Bear Point mound I obtained certain objects of interest which throw some additional light upon the habits of its builders.

A hemispherical piece of granite, having a slight concavity in its base, was probably used for grinding parched corn, a beautifully polished biconvex disc of chalcedony was of a suitable size and form to serve as a quoit. The vast amount of labor which must have been expended in shaping and polishing so hard a material, and its consequent great value, make it, however, doubtful whether it was used for this purpose. Other smaller disks, were possibly for pitching at a mark, or may have been used as markers or counters for some game. A single clay pipe shows that the Indians also indulged themselves in at least one of the luxuries of life.

ARCHÆOLOGICAL NOTES FROM WYOMING. By THEO. B. COMSTOCK, of Ithaca, N. Y.

(ABSTRACT).

THIS paper was presented in order to call attention to some remains of man's art and history, occurring along the route of Capt. Wm. A. Jones's Expedition to the Yellowstone Park in 1873, to which the writer was attached as geologist, as a limited edition only of the full report (2nd edition), containing an account of these relics, was issued from the Government Printing Office, entitled "Report upon the Reconnaissance of N. W. Wyoming, including Yellowstone National Park, made in the summer of 1873 by William A. Jones, Capt. of Engineers, U. S. A.— *With Appendix:* Washington, 1875."

At present there is no recorded knowledge of any facts or traditions which will enable one to pass final judgment upon the question of the age of these relics, but there is little evidence to prove that they represent a period very far in the past. They consist in part of flint and quartzite flakes, both rude and well-worked, the former being found mainly in the vicinity of the 41st parallel along the northern base of the Uintah Mountains, the latter being scattered thinly over a considerable area northward. Besides these occur rude hieroglyphs in soft rock, several peculiar stone heaps and stone circles, and other relics of less interest. All of these are sufficiently described in the report just mentioned, to which all who desire further information are referred.

NOTES UPON SOME EXPLORATIONS OF ANCIENT MOUNDS IN THE VICINITY OF GRAND RAPIDS, MICH. By W. L. COFFINBERRY AND E. A. STRONG, of Grand Rapids, Mich.

RECENT explorations and excavations among the numerous ancient mounds in the vicinity of Grand Rapids, undertaken by the Kent Scientific Institute of that place, and carried forward by the authors of this paper, with the assistance of other members of the Institute, have developed some facts of interest, to us at least, which will be given in detail through another channel. It is the object of the present paper merely to give, in a brief topical form, certain conclusions derived from these explorations.

1st. NUMBER OF MOUNDS EXAMINED. Eight groups, containing in all forty-six mounds have been seen and inspected more or less thoroughly, of which number, *fourteen* have been excavated and explored with great care. A typical group of seventeen mounds on the farm of Capt. A. N. Norton, about three miles below the city of Grand Rapids, on the bank of Grand River, was carefully surveyed and platted, and several of them thoroughly explored.

2nd. SIZE AND SHAPE. The mounds examined vary from two feet to fifteen and one-half feet in height, and from ten feet to one hundred and two feet in diameter.

In all cases they are more or less exactly conical, somewhat flattened at top, with a broad talus at the base; such a form as any conical mound of earth will assume after long exposure. The map of the Norton mounds (exhibited at the meeting) shows the form better than words can describe. In no case does the outline of the group show any appreciable figure or "totem."

3rd. MATERIAL. The material of which the mounds are composed seems in most cases to be gathered from the surface about the base of the mounds over such an extent as to leave no appreciable depression. Each mound is nearly homogeneous, and is usually composed of surface or alluvial soil. Only in a few cases has resort been made in their construction to the underlying gravels and clays. In most cases it is sufficiently evident that no

great interval of time elapsed between the beginning and the completion of each mound.

4th. AGE. That the mounds are very old can easily be established. Trees are growing upon the Norton mounds equal in size to some of the same species, standing upon the same kind of soil, which had *two hundred and sixty rings* of growth, while at their base are lying the remains of still larger trees which must have been giants while the former were saplings.

But more conclusive evidence of the great antiquity of these structures is found in the condition of the articles which many of them contain. Human bones are decomposed almost beyond recognition; only in favorable cases will they bear their own weight when exhumed. Even the dense shafts of the long bones of herbivorous animals are sometimes so tender that they can be rubbed to powder between the fingers. Copper is encrusted with a thicker coating of the carbonate than pieces of the same material found at the depth of several feet in the heavy drift in the same vicinity. Heavy marine shells, as well as those of the larger unios, are in a friable or pulverulent condition. Wood, bark, and all fabrics are entirely decomposed and returned to their native elements.

While these statements are true in general of all mounds explored by us, they are far more apparent in some cases than in others, which led us to question whether all the mounds of the same group are coeval.

5th. PURPOSE OR USES. One single mound, or rather the remains of one, has been observed which might come under the designation of *refuse heaps*. It was entirely removed years ago to make way for the dock and mill at Spoonville, Ottawa County, Mich. It is described by those who removed it, as a huge pile of ashes, shells, and fish bones, about fifteen feet high, forty-five feet wide, and one hundred feet long (these are minimum dimensions), and is in part at least recent.

About one-third of the mounds examined were clearly mounds of sepulture. The use of the others, or the motive which led to their construction, can only be conjectured.

It is quite reasonable to suppose that they were either monumental or commemorative, or were erected as observatories, the last supposition being the least probable. Mounds of this class

can in no way be distinguished from burial mounds by any outward signs. They are simply empty and structureless piles of earth mingled confusedly with burial mounds.

6th. INTRUSIVE MATERIAL. The late Messrs. Louis Campan and Rix Robinson, both of whom spent much of their lives with Indian tribes of the upper and lower peninsula of Mich., had their confidence, and were familiar with their manners and languages, used to say that their Indian friends uniformly declared that the mounds were not built by themselves, that they did not know their origin, but that they all regarded them with reverence and preferred to be buried near, or upon them.

7th. MATERIAL FOUND IN THE MOUNDS. This may be conveniently described under the following heads: *Human remains, fabrics, pottery and drinking vessels, stone implements, bone implements, and copper implements*, but for the sake of brevity several of these topics will be omitted.

These materials were intimately associated. Where human remains were wanting nothing was found, while in no case were skeletons exhumed without revealing something else of interest, often of all of the above named kinds.

A. HUMAN REMAINS. These were almost invariably found in an elongated, concave, irregularly oval pit, a foot or two below the natural surface of the ground, surrounded by whatever objects of interest the mound contained. The relative situation of this material being essentially as in the ordinary English barrows. The skeleton is not oriented, but the feet are turned indifferently in any direction; nor is there any uniformity in the posture of the body or in the position of the members. A half sitting or reclining posture has been observed, and in one instance a position much that of the skeleton from the cave of Menton, figured in Dana's Geology and elsewhere; more commonly, however, the limbs are violently flexed upon the body, or, as is still more frequently the case, the bones of the skeleton are confusedly mingled.

Frequently only the larger bones are found, and not one complete skeleton has been seen. Portions of a skull may be wanting, the long bones may be broken and the pieces dissevered, or some of the pieces may not be present.

In every instance the skull is flattened as if by the pressure and settling of the soil in the direction of the vertical axis of the mound, and this without any referenee to the position of the skull.

B. FABRICS. All the copper articles found bear traces of having been wrapped previous to deposition, in a coarse (apparently) woven cloth which uniting with the enerusting carbonate has been at once preserved and obscured by it. In several instances where the earth has been earefully cleared away from bone spears, flint implements, or even the common fragments of quartz pebbles, impressions of fabrics have been clearly visible.

The impressions are such as would be made by coarse, loosely woven cloth having about twelve or fourteen untwisted or slack-twisted fibers to the inch.

C. HOLLOW VESSELS. Several large marine shells were uncovered. They were all hollowed out apparently for carrying or storing water, and in one case perforated at the upper edge on opposite sides for suspension by a cord or thong. A few fragments of usual coarse pottery were also found with external markings as if formed and baked, or dried, in a basket of rushes or grasses, or perhaps both may have been used for such purposes. In addition to these, fragments of a much finer sort of hollow ware, of a different composition and covered with ornamental lines and marks either impressed or engraved, were exhumed.

So far as the authors of this paper are informed, these are quite extraordinary both in their form and their external markings, and unique in appearance. The upper part of the vessel sometimes appears to bear marks of having been formed by revolution as upon some kind of wheel, while the lower part is irregularly convex and usually has three or four strong bulges or protuberances.

The rim is well made; somewhat thickened, neatly beveled or rounded at top, and often ornamented with a check pattern produced by quick diagonal strokes of a pointed instrument. Below this is a plain band, bordered by grooves or rows of triangular pits, or both. The lower part of the vessel is ornamented with a variety of patterns, usually having some reference to the protuberences above mentioned.

These vases or vessels are small, having a capacity of one or two quarts at most, and in all cases were found in scattered fragments

as if they had been thrown, or placed, in the pit before it was filled, or while it was being filled. One only seemed to have been crushed by the settling of the mound, as the pieces were nearly in place. It contained a mass of irregular flint chips, such as is often found in these barrows.

Note.—In our explorations of the Norton group of mounds, we found nothing of reeent deposit, but in one mound on the farm of Mr. Royce, about a quarter of a mile distant, we found parts of a skeleton, consisting of a few broken pieces of the cranium, the sacrum, a few teeth, and some other pieces much decayed or burned, or both burned and decayed, as there was much charcoal in close proximity to the fragments of bones. Both charcoal and bones were not more than one foot and a half below the top of the mound, while the mound itself was about six feet high and forty feet diameter at the base, and considerably flattened by time.

In this mound we found nothing of interest at the natural surface of the ground and below it, as we did in the Norton group, except one small copper needle about one and one-fourth of an inch long, thickly coated with green oxide, and a few flint chips.

Recent Explorations of Mounds near Davenport, Iowa. By R. J. Farquharson, of Davenport, Iowa.

In the immediate vicinity of Davenport, Scott County, Iowa, and during the summer of 1874, a bit of "spade cultivation of history" was done which yielded remarkable results. The work was performed by the Rev. Mr. Gass, assisted by four theological students who were spending the summer vacation with him. In his account, published in the daily papers, Mr. Gass states, that his attention was called to the fact of the existence of these mounds, by the present owner of the land, Mr. G. Schmidt, who remembered very nearly the precise situation of each mound, though, the land having been in steady cultivation for more than twenty years, the prominence of the mounds above the surrounding surface had been reduced to almost nothing. These mounds had

been repeatedly dug into, but in the usual superficial way. A gentleman told the writer, that in the year 1860, he and his brother spent a summer's day, in digging a trench through one of these mounds, which at its deepest part (the middle of the mound) was three or three and a half feet deep. They only discovered some recent Indian bones.

But in this very mound, the thorough and systematic exploration of the German students to the depth of at least six feet below the present surface, and fully that much below the excavation of 1860, unearthed a rich store of archæological treasure.

The great depth below the actual surface would seem to indicate that some of the bodies (those in a sitting posture) were not placed in the ground, nor in a slight excavation, but were inhumed in a pit, which, from the presence of rotten wood, was probably covered over and surrounded with wood, thus resembling the circular stone graves found elsewhere in this country.

SITE OF THE MOUNDS. — This is well shown by the accompanying map,[1] for which I am indebted to the kindness of Mr. W. H. Pratt. The mounds are situated about one mile below the city of Davenport, on the immediate bank of the Mississippi River; having a general bearing NE and SW, or nearly parallel to the course of the river at this point, and distant from high water mark about two hundred and fifty feet. As will be seen by the map, all of these mounds are placed upon a strip of ground, whose average surface is only from eight to twelve feet above high water, thus disproving the assertion of a late writer (Mr. Alexander Delmar in the "Independent," May 30th, 1875), that "when the mound builders inhabited the Mississippi Valley, the alluvial deposits of rich black mould, which now render that portion of the country so fruitful, did not exist," but also the older one of Squier, that "none of these works (the mounds) occur in the lowest formed of the river terraces, which mark the subsidence of the western streams, ... while they raised them promiscuously in all others."

MOUND No. 1. (Plate 3, fig. 1.) The first or upper mound (a single mound though apparently double on the surface) had a diameter of thirty, and a height of four or five feet.

[1] Not reproduced.

The layers, from above, downwards, were unbroken; first, a foot of earth, then a layer of stones one and one-half feet thick (these stones came from the river and were nicely formed), then a foot and a half of earth, then a layer of shells two inches thick, then a foot of earth, and finally a second layer of shells four inches thick, immediately under which (*i. e.*, at a depth of five feet) the skeletons, all of adults, and five in number, were found. The skeletons were lying in a horizontal position, parallel and close together; three lay from east to west and so that the head of one rested on the shoulder of the next, while the fourth and fifth lay in the opposite direction, or heads to the west and feet to the east.

With the first three, or those with heads to the east, no relics were found, while with the latter, or those with heads to the west, all the following interesting objects were found.

A large sea shell (*Pyrula perversa*) with the axis and inner whorls removed; two copper axes, Nos. 6 and 8[2] (Plate 5, figs. 6 and 8), very nearly alike in form and weight, they were found back to back (*i. e.*, with flat surfaces in contact); they were both covered with cloth, which was removed, when the surfaces were unfortunately scraped on the spot with a knife, fragments of it, spared by the cleaning being now visible; a copper awl; one flint arrowhead; and two pipes, one representing a frog (Pl. 2, fig. 2), the other was plain. The human bones appeared, when first exposed, to be in a good state of preservation, but fell to pieces when moved.

MOUND No. 2. (Plate 3, fig. 2.) This was about 100 feet SW of No. 1, and though like it in outward form was quite different inside, in having no layers of shells, but several layers of stones, with a few scattered shells. At a depth of five feet, eight[3] skulls, with some fragments of bones, were unearthed. These were laying in a semicircle of five feet diameter, and each skull was surrounded by a circle of small stones. From the position of the skulls and bones, these eight bodies had been buried in a sitting posture.

In this mound were found the following articles. Two copper axes, Nos. 9 and 10 (Plate 5, figs. 9 and 10); two small hemispheres of copper, and one of silver, probably ear pendants; a canine tooth of a bear; a flint arrowhead; a mass of red pigment;

[2] These numbers refer to the descriptive table on page 304.
[3] In the plate the artist has drawn only five skulls and skeletons.

the vertebræ of a small snake (probably accidental). From this mound came the two fragments of skull shown at the meeting.

MOUND No. 3. (Plate 3, fig. 3.) This, the largest of the series, was 120 feet SW of the last described. Of this mound the Rev. Mr. Gass, its explorer, says "its outer and inner arrangements were quite similar to the first;" but in its further description the layers of stones and of shells were not mentioned.

At a depth of one and one-half feet were found two adult skeletons, lying in a horizontal position. From the freshness of the bones, from some oakwood covering them, as well as from the accompanying relics, glass beads, clay pipe, fire steel, and a silver ear ring, this was taken to be an intrusive burial of recent Indians. Two of the bones from these skeletons, a femur and a tibia, curiously mutilated by a sharp cutting instrument are preserved in the museum at Davenport.

Beneath these bones, at a depth of six feet, and under a thin layer of ashes, were found the bones of two adults and of one very young child. The posture of the adults is not given by the explorer, nor their relation to the infant's bones; these latter, however, were covered with a great many copper beads of various shapes and sizes, and by these were dyed of a deep green color; they were also surrounded by a circle of small red stones, arranged like the rays of the sun.

Besides the beads and stones were found the following. Five copper axes, Nos. 1, 2, 3, 4 and 5 (Plate 5, figs. 1, 2, 3, 4, and 5), all covered more or less with cloth; two carved stone pipes, one plain and the other having the form of the ground hog (Plate 2, fig. 1); many teeth of animals, including several canines of the black bear, one polished and with holes drilled; the incisors of small rodents, muskrat, gopher, etc.; the enamel from incisors of a large rodent, probably the beaver; one flint arrowhead; three broken pots, with bones of the soft-shelled river turtle adhering to the insides of the fragments; two pieces of galena; yellow pigment (ochre).

MOUND No. 4. (Plate 3, fig. 4.) This was 250 feet SW of the last, and was of a simple structure containing neither layers of stone nor of shells. At a depth of six feet, and under a layer of six inches of ashes were found four adult skeletons, lying close

together, with which was one copper axe. From the earth in which the skeletons lay, it could be distinctly seen that they had been enveloped in cloth, or some woven material, and at their feet, at a depth of four feet, was a round heap or altar (three feet high) of five stones nicely joined together. As stated above, the only relic here found was the copper axe, No. 7 (Plate 5, fig. 7).

MOUND No. 5. (Plate 4, fig. 5.) This was distant 100 feet west of No. 1. In size and internal arrangement it much resembled No. 2, *i. e.*, with no strata of shells, but with several layers of stones, with loose shells between them.

After some five feet of stones, shells and earth had been cleared away, a skeleton was exposed, upon which was a layer of six inches of hard clay. Upon closer examination it appeared that the bones were the remains of two skeletons, for several ribs, and pieces of skull, and four thigh bones, lay together in a little heap; and somewhat to the side of them were a few bones of the arm, some ribs and a lower jaw. Three feet further to the NW and at the same level, was a round heap of stones (about four feet high) like that found in No. 4. On this heap lay two very strong thigh bones, and three ribs, placed diagonally across each other. There were also a few bones leaning against the heap at one side. Of the stones some were partly burned to lime, and all showed more or less the marks of fire, while the bones, on the other hand showed not the slightest trace of it. (Plate 4, fig. 5, A.)

A few pieces of charcoal were found by the stones, as in two previous mounds, and the heap was doubtless an altar of sacrifice.

Four or five feet to the south of this altar was found a large quantity of the remains of human bones, in complete confusion, as if they had been scattered there. Three feet further south, under a layer of shells six inches in thickness, were found two broken pots, one flint arrowhead, a finely wrought stone pipe and a few stone implements (whetstones).

Four feet further south lay another skeleton from east to west, and six inches above its skull a copper axe, No. 11.

In this mound were also found, some incisors of small rodents, canines of the common bear, and a small circular piece of the human cranium, one inch in diameter. Coming from the squamous portion of the temporal bone, and strongly recalling the rondelles of prehistoric trepanning exhibited in France last summer.

MOUND No. 6. (Plate 3, fig. 6.) This was about 100 feet SW of No. 5. It was smaller in circuit and lower than the others, containing fewer stones, but more shells. The skeletons in this lay scarcely three and a half feet deep. Here again the bones of the same parts of the body, and of the limbs lay often several feet apart. Those of only one skeleton (or at most two) lay in natural order. There may have been four bodies in all, but it was impossible to settle the matter definitely. The following articles were found in this mound; two broken pots, a carved stone pipe, a stone knife, and a flint arrow head.

MOUND No. 7. (Plate 4, fig. 7.) This was a small mound, out of the line of the others, being fifty feet west of No. 6. It was also like it in size, but differed in having a layer of stones and under that a thin layer of shells.

Three and a half feet below the latter were some fragments of bones, almost entirely crumbled to dust, and two pots, one broken the other almost entire, and some arrowheads.

MOUND No. 8. (Plate 4, fig. 8.) This mound, somewhat larger and higher than the average, was distant 200 feet south-west of No. 6, thus being in the general line or range.

After four and one-half feet of stone, earth and shells had been removed, two skeletons (supposed to be those of an adult female and of a child) were discovered. They lay near together and from east to west. On the right side of the large skeleton were two broken pots, eight pieces of galena, two small arrowheads, and a number of stones, of various sizes, shapes and colors, which were laid in a jagged or star-like circle. There also was found a piece of mica, six inches long and three and one-half inches wide.

Over and around all these articles was a loam of some decayed material. They had probably been surrounded and covered with some light protecting stuff, as was most plainly to be seen in the case of the pots.

MOUND No. 9. (Plate 4, fig. 9.) This mound was about 100 feet N by W of No. 1. This had been reduced both by cultivation and hauling away the dirt; over two hundred wagon loads having been taken away, thus reducing the original height by three or four feet. Near the present surface, a few shells, and also a few sea-

board stones were found. About three and one-half feet down, two skeletons were found in a horizontal posture, lying from east to west, with the bones much decomposed, the skulls were about four feet apart, one east and the other west. The western skull was preserved and is No. 8 of the Davenport collection. The eastern skull was so tender that it fell to pieces in handling, the lower jaw (which was in place) was however preserved, and is much stained by the copper axe No. 12 (No. 6 of the photographs, reproduced as Pl. 1), which was found in contact with it.

A carved stone pipe was found between the bodies. An obsidian arrowhead, flakes of the same, and three small arrowheads of white chert, were found in close proximity to the eastern, or stained, skull. A small tinted arrowhead was also found two feet nearer the surface. One earthen pot, much broken up, was found near the second skull. In this mound was also found the implement made from the coracoid bone of a river turtle, and probably used as a spoon, or rather a spatula or skimmer.

In several of these mounds, broken pottery was found scattered between the surface and the deeper parts, where the bones were found, as if pots had been placed on the surface of the mound, as well as within.

It was remarked by the explorers that in some cases of horizontal burial the faces of the bodies were downward.

As the Rev. Mr. Gass was this summer (1875), passing by mound No. 3, he noticed that the earth of the edges of the excavation of 1874, had been much washed by recent rains, and saw protruding therefrom, the curious copper implement, shaped like a spoon, which will be described further along.

DESCRIPTION OF THE SEVERAL ARTICLES FOUND IN THE MOUNDS.

SILVER. The only ornament of silver was a hollow hemisphere of beaten plate, of seven-tenths of an inch in diameter (Plate 6, fig. 19), found in company with two hemispheres of copper, of the larger of which it is an exact counterpart.

On the surface of the spoon shaped implement from mound No. 3, appears a surface which seems coated or washed with silver.

COPPER. The Davenport collection of copper implements at present consists of thirteen copper axes,[4] of which six are more or

[4] Since the above was read, the number of copper axes has been increased to 20, all of which are represented on Plate 5.

less covered with cloth; four copper awls or borers; many (over 100) copper beads; and the curiously spoon-shaped implement.

The axes are all of two forms, one plano-convex, the other with flat sides. They were cold wrought by hammering, some retaining the original scales or laminæ on the surface; none of them show signs of use, and are not notably harder at the edge than elsewhere.

The following table shows their source, size, shapes and weight.

TABLE A.

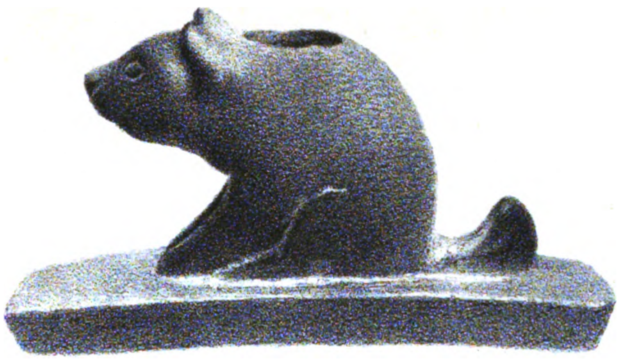
NO.	MOUND.	WEIGHT; POUND AVOIRDUPOIS.	SHAPE.	LENGTH. †	WIDTH OF EDGE.	WIDTH OF UPPER END.	GREATEST THICKNESS.
1	No. 3	1.0721	Flat-sides	6 7/8	2 1/8	1	1/2
2	" 3	1.1564	" "	7 1/2	2 3/8	1 1/8	3/8
3	" 3	0.5387	Plano-convex	4 5/8	2 7/8	1 3/8	1/2
4	" 3	0.1056	" "	5 3/4	2 3/4	1 1/2	3/8
5	" 3	0.9961	" "	5 1/4	2 5/8	1 3/8	1/2
6	" 1	0.4242	" "	3 3/4	2 1/8	1 3/8	3/8
7	" 4	0.8114	Flat-sides	5 5/8	3	1 7/8	1/4
8	" 1	0.4602	Plano-convex	3 5/8	2 1/4	1 1/2	3/8
9	" 2	0.8664	Flat-sides	6 1/4	2 3/4	1 1/4	1/4
10	" 2	0.5085	Plano-convex	3 1/4	2 1/4	1 3/8	3/8
11	" 5	1.6575	" "	6	3 1/4	1 7/8	7/8
12	" 9	0.8743	Flat-sides	5	2 1/2	1 3/4	1/4
13	*	0.4987	Plano-convex	4	2	1	4/10

Of these axes Nos. 1, 2, 3, 4, 5, and 12 (Pl. 1), are more or less covered with cloth, and are those photographed. Besides these, Nos. 6 and 8 found together in mound No. 1, were also covered with cloth, which was unfortunately scraped off, when being cleaned of dirt; this fact is shown by the small patches of cloth which have escaped. Of the four copper awls, three came from mounds, and being of the ordinary kind need no description. The copper ear-pendants are thin hemispheres of beaten plate (Plate 6, figs. 20 and 21), the larger of eight-tenths of an inch in diameter, and of thirty-four grains weight; the smaller of one-half

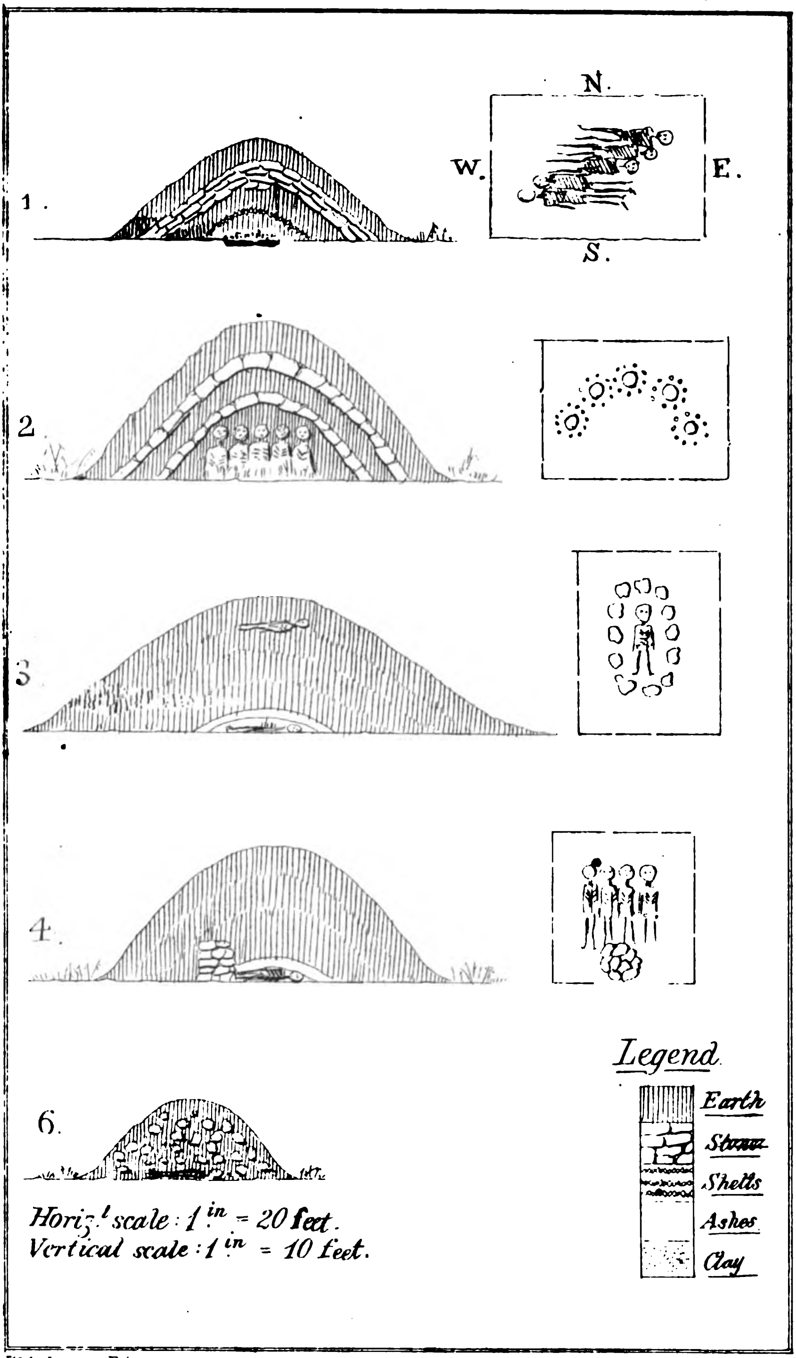
* A mound near Princeton, Scott County, Iowa.

† The measurements in this table are given in inches.

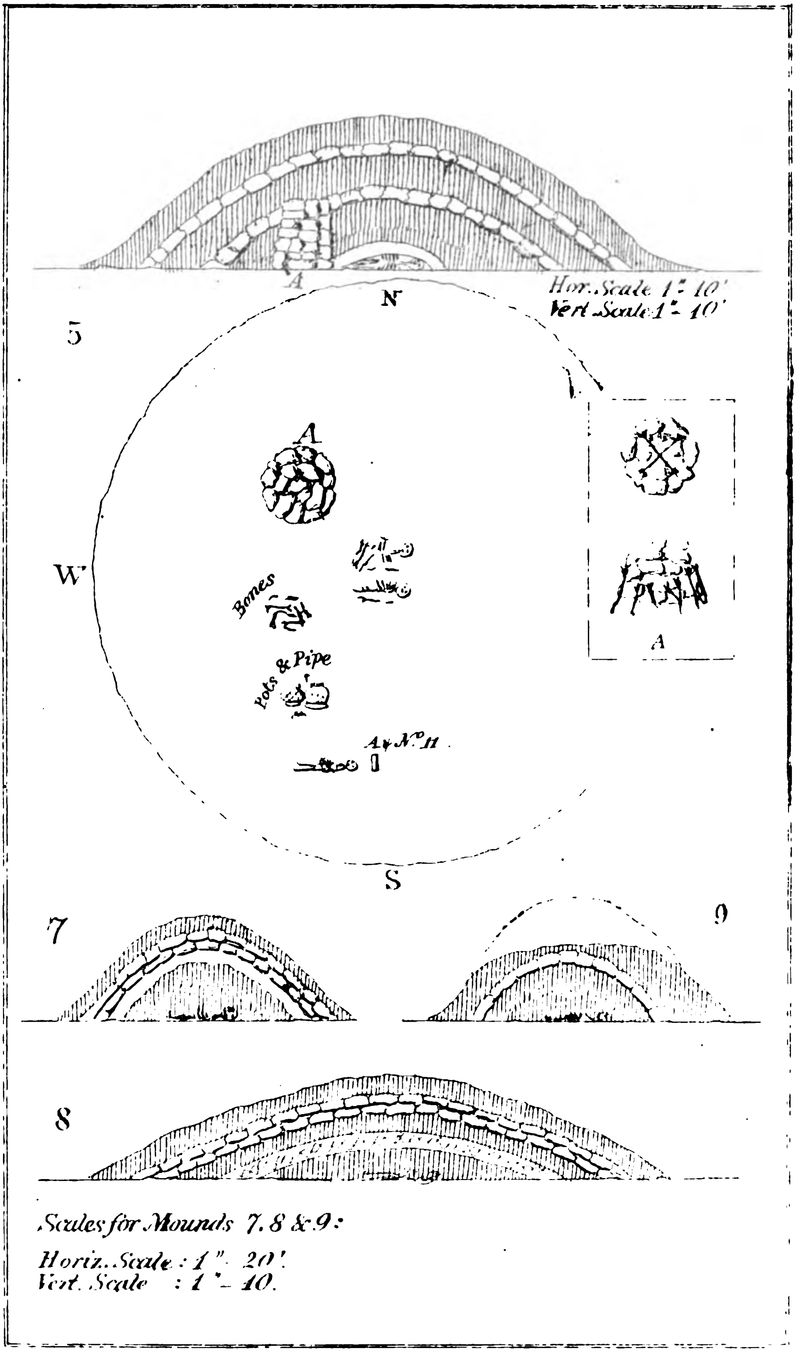
Copper Axe wrapped in Cloth
From Mound near Davenport, Iowa.

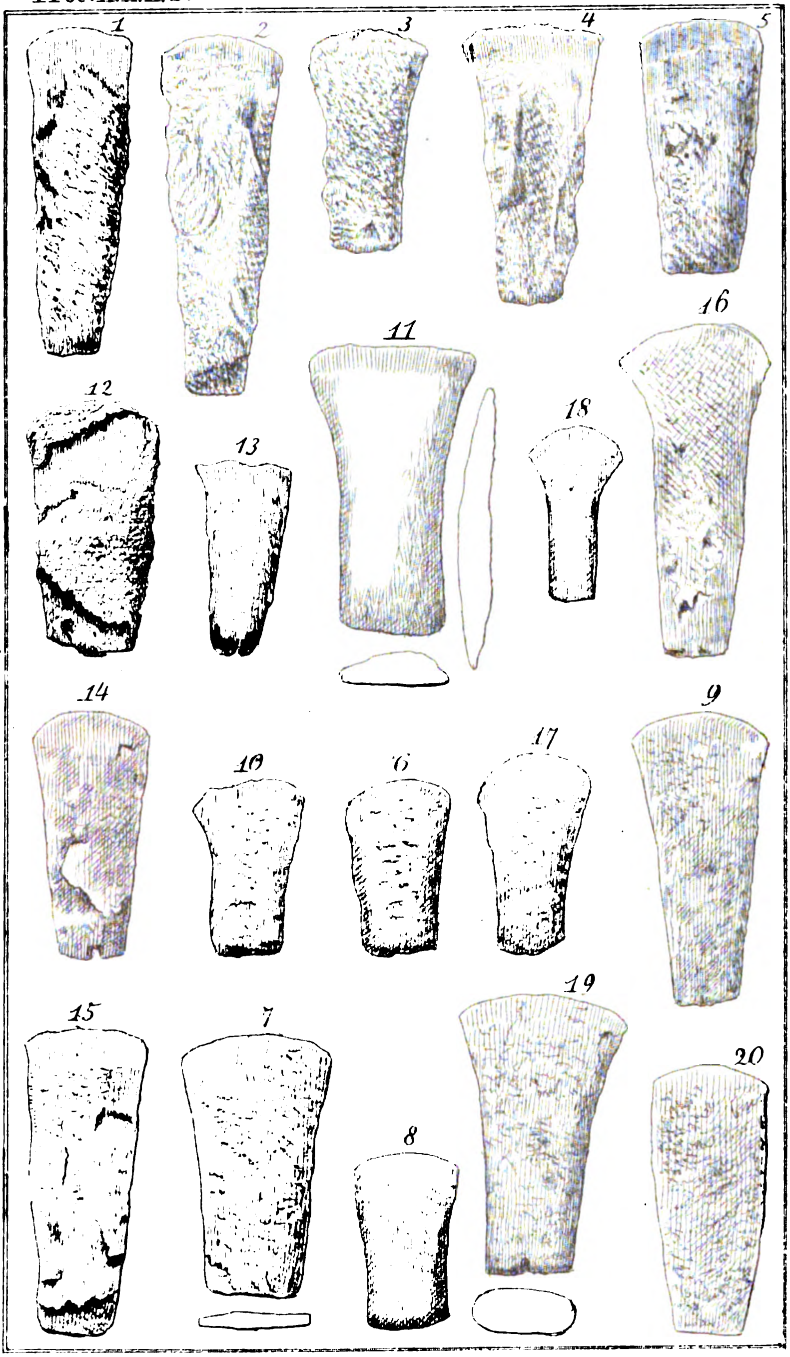


Stone Pipes
From Mound near Davenport, Iowa.

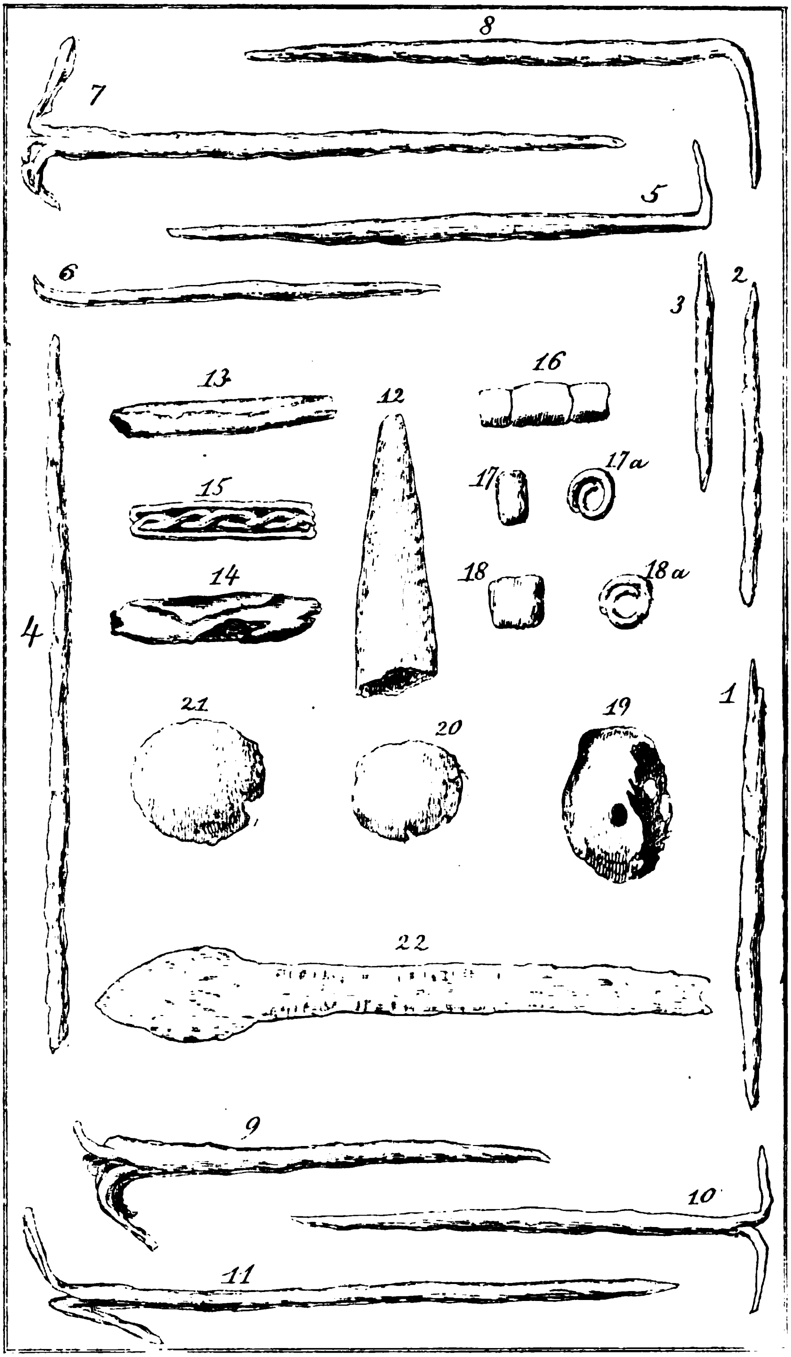


W O Groner, Delt. A. Hageboeck, Lith.


A
Hor. Scale 1" = 10'
Vert. Scale 1" = 10'
N
5
W
A
Bones
Pots & Pipe
A + No. 11
A
S
7
9
8
Scales for Mounds 7. 8 & 9:
Horiz. Scale : 1" = 20'.
Vert. Scale : 1" = 10.



W. H. Pratt, Del. A. Hageboeck, Lith



W. H. Pratt, Del. A. Hageboeck, Lith.

an inch in diameter, and of ten grains weight. The spoon-shaped copper implement which came from mound No. 3 (but in what relation to other things recovered from that mound is not known), has evidently been produced by hammering, but from some marks on the surface, not from an original piece of copper, but from a small bar already bearing these marks, which are obliterated in most places by the action of the hammer. Its dimensions and weight are as follows:—Total length, 82 millimetres, length of the spoon part 22^{mm}; breadth of handle 8^{mm}, breadth of spoon part at broadest part 14^{mm}, average thickness of the handle 2^{mm}; thickness of point of spoon part 1^{mm}, thickness of middle part of spoon part one-half of a millimetre. Total weight 86 grains, and it appears to be of pure copper. On one side of the handle nothing but the marks of the round face of the hammer is visible, but on the other a series of indented lines, in rows up each margin for the distance of an inch, and again in the arc of a circle just at the junction of the handle and broad part, similar marks are plainly visible with a lens. This ornamentation is like the milling on the edge of a coin, and was evidently made there before the article was hammered to its present shape. Upon the same side is seen a spot of silver. (Plate 6, fig. 22.)

The copper beads may be divided into three classes. 1st, small tubes of the average length of one inch, and of the average weight of sixteen grains. 2nd large tubes of an average length of one and one-half inches, and of an average weight of 115 grains; and 3rd, of very short tubes, almost round, averaging three-tenths of an inch long, and sixteen and one-half grains in weight. All of these beads or tubes are made of thin strips of copper, rolled up after having been beaten out thin by hammering. (Plate 6, figs. 12, 13, 14, 15, 16, 17, 17a, 18, and 18a.)

CLOTH. These interesting and undoubted specimens of mound-builders' cloth have been preserved by the antiseptic action of the salts of copper, in all probability of the carbonates. In all the specimens, one thread, say of the warp, is double or twisted, and there are about four to the one-fourth of an inch. The texture of the cloth is best seen on both sides of No. 12, No. 6 of the photographs (Plate 1); here, however, in many places the original vege-

table fibres have entirely disappeared, their forms being exactly retained, and their places taken by fibrous crystals of the carbonate of copper. This fact is quite apparent under the microscope, and was further confirmed when upon slightly heating a fragment on a glass slide, the whole form melted away, dissolved in water of crystallization.

In No. 2 the warp is evident, and consists of a single thread, not so tightly twisted as that of the woof. The cloth on this axe appears to be of a different style of weaving, there being only two and one-half threads of the warp to the one-fourth of an inch, but it may be that it is only the wrong side of the cloth.

The fibre under the microscope appears to be a kind of hemp, possibly the *Apocynum cannabinum* formerly used by the Aztecs.[5]

The thread is spun evenly and of a pretty uniform diameter of one millimetre, or the one twenty-sixth of an inch, in diameter, which measurement very nearly agrees with that made by the late Dr. Wyman, from cord marks on mound pottery.

MICA. Besides the large piece of $6\frac{1}{2} \times 4$, mentioned above, quite a number of small pieces were found.

PIPES. The pipes, ten in number, were all from the mounds below Davenport, with one exception, and that came from a mound in Rock River, Rock Island County, Illinois. They are all of the so-called mound pipe patterns, and three of them carved with effigies, one of a frog (Pl. 1, fig. 1), another of a bird, and the third of a ground hog (Pl. 1, fig. 2).

The material of which they are composed varies from a very hard green stone, the rough varieties of catlinite, or an approach to it, to others of a marley nature, effervescing with acids, quite soft, and much corroded by the action of soil water.

GALENA AND RED OCHRE. The masses of galena and red ochre need no description nor comment, except perhaps the great quantity of the latter found in mound No. 3.

SHELLS. Besides the ordinary river shells constituting the

[5] Since the above was read, I have received from Col. D. A. Robertson, of St. Paul, Minn., some of the fibres of the *Urtica gracilis*, which he suggests may have been those used.

layers in the mound, large sea-shells were found; in some instances, only the axes and parts of the inner whorls remain, but again in others, the shells were found nearly as they were fashioned from the original.

The shell from mound No. 1 is a *Pyrula perversa*, which has been cut through in its length, about an inch above the centre of the base, and the axis and whorls removed; there is a hole of an inch in diameter, in the centre of the base.

This shell in the line of section has a long diameter of thirteen, and a transverse of seven inches. Its internal capacity is 104 cubic inches, nearly four pints.

Another fine specimen of a sea-shell has recently come into the museum of the Davenport Academy, from a mound in Pine Tree Creek, Muscatine County, Iowa, twenty miles from Davenport.

This is a species of *Cassis*, and, except in being broken across its length, is a perfect specimen. It is much thinner and lighter than the *Pyrula*, but whether from greater age, or from its original thinness was not made out. In the line of section it has an extreme length of nine inches and a breadth of six inches, its internal capacity is of 152 cubic inches or five and one-half pints. The greatest length of the shell being nine and one-half inches with a width of six, the section being made very near one side, thus giving a much greater depth than in the Pyrula.

ARROWHEADS AND FLAKES. The arrowheads found with the copper axes and bones at the mounds, were ten in number. They were of the usual form and size, with exception of one found in mound No. 9, which was very small, only $1 \times \frac{1}{2}$. It was beautifully wrought and seems now as if just out of the hands of its maker; it is of white flint or chert.

Most of the others differ neither in form nor material from hundreds of those found on the surface.

However, perhaps another exception should be here made in favor of an arrowhead and two flakes from mound No. 9, of a dark, almost black material, looking like glass and at first taken to be obsidian from its marked resemblance to other arrowheads in our Museum marked obsidian and brought from Utah; but

upon applying the blow-pipe flame to a fragment, it proved refractory and was thought to be a smoky quartz.[6]

BONES AND TEETH OF ANIMALS. In mound No. 2 was found, what was called "a string of snake bones," being the remains of a small snake, which may have been introduced accidentally, as there is no evidence of their having been strung on a thread like beads.

The lower jaw, and also detached incisors of muskrats and other small rodents, probably gophers and ground squirrels, were quite abundant, as also were the tips of horns.

In one mound was found the enamel from the incisors of a bear, but the rest of the teeth were entirely gone. Adherent to the inner surfaces of the fragments of some of the large pots or vases were bones of the river turtle, from whose shoulder blade the curious spatula found in mound No. 9 was made. This is a fragment, the rounded part of the coracoid bone having been broken off, it is four inches long by one and one-half inches wide. It was doubtless used as a spatula or skimmer. Many teeth of the common black bear were found, both molars and incisors of the latter, some of large size were polished and perforated, doubtless for using as ornaments.

In this connection (though found in one of the mounds at Albany, Illinois) may be mentioned the curious specimen of what appears to be the canine tooth of a large bear (the grizzly); from its perforation and highly polished surface, it has evidently been used as an ornament. It appears to be the half of a tooth, the section made longitudinally through the middle. The outside presents exactly the appearance of a natural tooth with the enamel removed or worn off; but regarded upon the other side, the great size of the cavity, and its running up to the extreme end of the tooth gives the idea of a false tooth made from a long bone. Since the above was written a small section was taken out, and upon examination under the microscope, the substance proved to be bone and not dentine.

This false tooth has a length of five and a width of one and one-fourth inches; it has four holes near the middle of the convex

[6] Since the above was written, we have succeeded in melting the edges of these specimens, thus showing them to be obsidian.

edge, evidently for suspension; at the fang end are two rows of holes (not bored entirely through) one five and the other six in number; at the opposite end the site of the enamel is marked out by a curved line engraved about a line in depth.

POTTERY. Besides fragments in nearly every one of the mounds, at least two pots were found near the bottom in company with the bones and other relics.

Only one pot was received entire and this was from mound No. 7, which contained besides, only the fragments of another pot, an arrowhead and some human bones.

This pot is of a reddish color not glazed, of rude workmanship, and evidently made by hand; the bottom is not level, nor the top rim truly circular. Its dimensions are as follows: height 5½ inches, diameter of bottom 2¾ inches, upper margin elliptical, with a major axis of 5½ and a minor of 5 inches.

The ornamentation consists of a crenated margin, then below a ring or protection corresponding to a series of holes on the inside, both made by indentation from within. The neck of the vessel is contracted and marked by a girdle of vertical indentations, each an inch long and close together. The internal capacity is seventy cubic inches or about two and one-half pints. One of the two larger vases with bones of the turtle adherent, found in No. 3 mound, in close connection with the five cloth covered axes, has been nearly restored by the patient labor of our curator, Mr. W. H. Pratt. Its description is as follows; thickness ¼ inch, height 11 inches, diameter of rim 7½, diameter of base 4 inches, circumference of rim 24½ inches, of base 13 inches, of neck 23 inches, of bulge or greatest circumference 26 inches; internal capacity 325 cubic inches, about 1 gallon and 3 pints. Ornamentation rude, from rim to neck small indentations, with a rim of large knobs or protuberances corresponding to holes on the inside; on upper part of the body, rings and rude figures made by a blunt point.

A few fragments of pottery were found where the impressions were made by a string or thread; these when copied in gutta percha were found to be of two kinds, *i. e.*, from single and from double twisted threads. The impressions were in small triangular divisions separated from each other by rows of holes, and it was

not easy to discover any mode by which they could have been made.

The most curious and interesting specimen of pottery in the Davenport collection is a terra-cotta ring or pulley, which nearly resembles the stone one described and figured by Mr. Rau, in his article on "Stone Drilling Without Metal" (Smithsonian Report, 1868), the original of which is in the Blackmore Museum. (Flint Chips, p. 511).

The following is a brief description of this article: —

Color almost black, fracture dark gray, white spots effervesce with acid (probably pounded shells), well baked, greatest diameter $1\frac{1}{16}$ inches, thickness at outer margin $\frac{3}{4}$ inch, diameter of central aperture $\frac{5}{8}$ inch, thickness at edge of the aperture $\frac{1}{2}$ inch. Depth of the groove $\frac{1}{8}$ inch, width $\frac{3}{4}$ inch. From this groove eight holes pass to the central opening; they are not quite straight probably from having been warped in the baking. The stone specimen figured by Mr. Rau is over two inches in diameter, and the central aperture is larger, but otherwise the implements are very much alike.

HUMAN BONES. Near the surface of mound No. 3, were found some bones, quite fresh and accompanied by a fire steel, a clay pipe and glass beads. Evidently an intrusive burial of a comparatively recent period.

Two of these bones are preserved in the Davenport Museum, on account of their strange mutilation; a femur, which has been cut across its lower end by repeated blows of a sharp cutting instrument; and a tibia, from which a slice of bone has been taken out by a glancing blow from the same.

Of the bones found at the bottoms of the mounds, very few were preserved, as they were so fragile as to crumble away upon being handled.

In this respect, presenting quite a marked contrast with the condition of the bones got from the mounds of Albany, Illinois, by our Academy in 1873.

Besides a difference of age, the difference of the two sites might account for it. The Albany mounds being on a high ridge with good drainage and composed of a sandy loam, while the Davenport

mounds are but a few feet above high-water mark, have no drainage and are of alluvial soil.

From mound No. 2, with copper axes and copper beads, we have two fragments of skulls, each being the frontal bone, with the nasal bones attached, nothing of the shape of the skull can be inferred from them, but both indicated a very highly arched nose. From mound No. 9 was recovered a skull, in connection with copper axe No. 12, which is in a pretty good state of preservation. Its measurements are given in the following table, together with the corresponding measurements of a mean, or average, of three Sioux crania, from Indians who died in captivity in Davenport; of nine crania from the Albany mounds; of eleven crania from Rock River Mounds; and of four from a mound in Henry County, Illinois.

TABLE B.

RACE.	HORIZONTAL CIRCUMFERENCE.*	LONG DIAMETER.	TRANSVERSE DIAMETER.	INTERNAL CAPACITY.†	DISTANCE OF FORAMEN MAGNUM.	RATIO OF DISTANCE.	RATIO OF DIAMETER.
Mean of three Sioux.	20.5	7.03	5.1	77.64	2.0 ‡	0.284 ‡	0.725
Mean of nine, Albany.	19.8	6.8	5.1	68.00	2.3 ‡	0.335 ‡	0.768
Mean of eleven, Rock River.	20.15	7.0	5.4	74.48	2.0 ‡	0.286 ‡	0.771
Mean of four, Henry Co., Ill.	19.5	7.0	5.2	74.47	2.14 ‡	0.305 ‡	0.743
One, Davenport.	19.5	7.0	5.25	76.20	1.8 ‡	0.269 ‡	0.752

* The measurements are given in inches.
† In cubic inches.
‡ Not reliable, for correct measurement see Table C.

TABLE C.

MEASUREMENTS OF MOUND SKULLS; ALSO OF SIOUX SKULLS, IN DECIMALS OF A METRE.

FORAMINAL DISTANCE TAKEN WITH WYMAN'S INSTRUMENT, THEREFORE MORE RELIABLE THAN THOSE IN TABLE B.

NO.	HORIZONTAL CIRCUMFERENCE.	LONG DIAMETER.	TRANSVERSE DIAMETER.	VERTICAL DIAMETER.	CAPACITY IN CUBIC CENTIMETRES.	FORAMINAL DISTANCE.	FORAMINAL RATIO.	RATIO OF DIAMETER.	MOUNDS.
1	.546	.200	.120	.140	1190	—	—	.600	Albany, Ill.
2	.483	.162	.128	.140	1190	.062	.382	.790	Albany, Ill.
3	.495	.174	.130	.135	1020	.077	.442	.752	Albany, Ill.
7	.508	.170	.140	.125	—	—	—	.823	Albany, Ill.
8	.495	.175	.135	.140	1249	.065	.370	.771	Davenport, Mound No. 9.
9	.508	.171	.140	.140	1334	.062	.362	.818	Rock River, Ill.
10	.508	.167	.148	.140	1135	.070	.419	.886	Rock River, Ill.
11	.533	.180	.150	.145	1362	—	—	.833	Rock River, Ill.
12	.457	.167	.128	.140	1021	—	—	.766	Rock River, Ill.
13	.522	.185	.130	.150	1362	.089	.427	.702	Rock River, Ill.
14	.483	.171	.138	.140	1192	.079	.460	.807	Henry County, Ill.
15	.508	.185	.138	.145	1306	.081	.443	.745	Henry County, Ill.
16	.457	.170	.130	.140	1185	.078	.448	.764	Henry County, Ill.
17	.533	.185	.135	.140	1249	.072	.389	.730	Henry County, Ill.
18	.508	.180	—	.140	—	—	—	—	Rock River, Ill.
19	.533	.196	.140	.140	—	—	—	.704	Rock River, Ill.
20	—	.200	.128	—	—	—	—	.640	Rock River, Ill.
21	—	.180	.137	—	—	—	—	.761	Henry County, Ill.
23	—	.178	.140	.140	—	.073	.410	.730	Albany, Ill.
24	—	.184	.139	.150	—	.088	.478	.755	Rock River, Ill.
26	—	.200	—	—	—	—	—	—	Shell Bed, Rock Island.
27	.482	.170	.125	.140	936	.076	.388	.735	Albany, Ill.
28	—	.177	.135	.140	—	—	—	.762	Albany, Ill.
29	.507	.177	.130	.145	1137	.088	.440	.734	Albany, Ill.
	.503	.179	.134	.140	1188	.075	.432	.755	Mean.
	18	24	23	21	15	14	14	22	No. of skulls measured.

SIOUX SKULLS.

1	.520	.180	.138	.145	1319	.085	.416	.766	Died in captivity at Davenport, Iowa.
2	.533	.183	.140	.150	1224	.077	.415	.765	
3	.507	.177	.136	.140	1224	.082	.463	.768	
	.512	.180	.138	.145	1256	.081	.431	.766	Mean.
	3	3	3	3	3	3	3	3	No. of skulls measured.

The next table shows the comparative measurements, in decimals of a meter, of seven tibiæ of mound-builders, and of one Indian tibia, being the mutilated bone previously mentioned as coming from the surface of mound No. 3.

TABLE D.

NO.	TRANSVERSE DIAMETER, PROXIMATE END.	LEAST CIRCUMFERENCE.	LENGTH.	ANTERO-POSTERIOR DIAMETER.	TRANSVERSE DIAMETER.	PERI-METRAL INDEX.	LATITUDINAL INDEX.	MOUNDS.
1	Broken	.060	.338	.036	.022	—	.611	Albany, Ill.
2	.078	.074	.388	.038	.024	.210	.631	Albany, Ill.
3	Broken	.075	.401	.042	.023	—	.547	Albany, Ill.
4	.076	.082	.390	.040	.026	.192	.650	Albany, Ill.
5	.074	.075	.392	.040	.023	.188	.575	Albany, Ill.
6	.076	.082	.400	.038	.022	.190	.571	Rock River, Ill.
7	.083	.094	.400	.040	.026	.207	.650	Pine Creek, Iowa.
	.077	.060*	.387	.039	.023	.195	.605	Mean.
	Broken	.075	.375	.036	.021	—	.583	Indian from Mound 3.

Diseases. Evidence of the prevalence of syphilis was quite common in the form of nodes. One skull from an Albany mound was of so great a weight and thickness, and also in such an extraordinary state of preservation, among others so light and easily broken, as to suggest the idea of the individual having been afflicted with rickets during life.

If the rondelle of bone found in mound No. 5, which evidently came from the squamous portion of the temporal bone, was removed during life, it would indicate the existence of the practise of trepanning, already known to have been practised by the prehistoric men of Europe; the finding at some future period of a cranium having a perforation with a healed edge would settle the question.

But the most singular manifestation of disease was found in the

cervical vertebræ, shown in a peculiar roughening of the articular surfaces, and also by a true or bony anchylosis of these points.

It was first noticed in a dentata, or second cervical vertebra, found in a mound in Rock River, Ill. Here the lower articular surface on the left side was affected. This was thought to be the accidental product of disease or injury, until in looking over some vertebræ from the mounds at Albany, Ill., another second cervical vertebra was found, with the same surface (the lower one on the left side) affected.

In a third instance, from a Rock River mound, the second, third and fourth cervical vertebræ were firmly united together, and the disease must have extended yet further down, as the lower articular surface of the fourth shows where it was united with the fifth; how much further the disease extended is not known, as the other bones were lost.

In a fourth case, also from a Rock River mound, the second, third and fourth vertebræ were affected, the articular surface roughened, and some united together by bony anchylosis; here again the disease extended below this, but the bones were lost.

In all these cases, the skeletons were those of adults, indeed one was of extreme old age, as shown by the loss of the teeth and of the alviolar processes.

In no case were any signs of disease found in the cranium, or indeed in any other bones than the cervical vertebræ.

This is certainly not a common disease now, and although rare, the instances of cure by bony anchylosis (the only way in which a true cure can take place) are even yet more rare, Nelaton, in his "Pathologie Chirurgicale" has only been able to note twenty-five recorded cases of such an event.

Now as the space of one year is the shortest possible time allowed by authorities for such a cure to take place, and as during all this time the parts must be kept absolutely at rest and the person so afflicted being entirely helpless, the inference is a strong one, that these people were not in a savage state. They must necessarily have been in such a state, in the progress of advancement in civilization, as to be possessed of an accumulation of food, the requisite leisure of persons nursing the sick, and of dwellings sufficiently comfortable to protect them from inclemency of the weather in this latitude; without those elements of civilization those persons would inevitably have perished.

GENERAL REMARKS. The following few general observations may perhaps be hazarded.

An examination of the condition of the edges and surfaces of the different copper axes, will show, I think, that none of them could ever have been used as implements; thus affording another strong argument in support of the theory which places most of the copper articles taken from the mounds in the category of ornaments, or, perhaps, more strictly speaking of treasures, than in that of tools. The wrapping of some of these so-called axes in a perfect envelope, or sack of cloth, would be another indication of their being regarded as treasures. The terra-cotta pulley was no doubt used in a bow-drill, as suggested by Mr. Rau in his article on stone drilling without metal. (Smithsonian Report, 1868).

The false grizzly bear's tooth seems to point to a somewhat advanced state of civilization, certainly of art; for people use natural ornaments such as gems, etc., long before they are prompted by an improved taste, or are skilled enough in the arts, to imitate them.

EXPLANATION OF PLATES.

PLATE I. Copper Axe wrapped in Cloth, natural size, from Mound No. 9.

PLATE II. Pipes; the upper figure represents the pipe found in Mound No. 3, and the lower figure one found in Mound No. 1.

PLATE III. Sections of Mounds.

PLATE IV. Sections of Mounds. In those plates the numbers of the figures correspond to those of the mounds. Two mistakes are to be noted. In plate III, fig. 2, the artist has drawn five skulls and skeletons, when there should be eight. Also, the engraver has failed to reproduce the layers of clay in any of the mounds, though he has it in the legend.

PLATE V. Copper Axes. The numbers of the figures correspond to those of Table A. The first 13 are those of that table; the remaining 7 are axes obtained since the Detroit meeting, and from mounds near Toolsboro, Louisa Co., Iowa. All are one-fourth the natural size. Some of these latter axes had a covering of cloth, notably No. 16, as shown in the plate.

PLATE VI. Various Copper Implements.

Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, are copper awls, or hair-pins (the latter with bent ends), one-half the natural size.

Fig. 12. Large copper bead, length 1¼ inches, weight 115 grains.

Figs. 13, 14, 15. Medium sized beads, length 1 inch, weight 16 grains.

Figs. 16, 17, 17_a, 18, 18_a. Small beads, length three-tenths of an inch, weight 12¼ grains; all of the natural size, and from Mound No. 3.

Fig. 19. Silver ear pendant, weight 13¼ grains.

Figs. 20, 21. Copper ear pendants, weight 10 and 34 grains; all of the natural size and from Mound No. 2.

Fig. 22. Spoon-shaped implement, weight 86 grains; of the natural size, and from Mound No. 3.

THE ANCIENT MEN OF THE GREAT LAKES. By HENRY GILLMAN, of Detroit, Mich.

ABSTRACT.

IN former papers, in placing upon record some of the more important of the discoveries of the writer relating to the ancient inhabitants of the region of the Great Lakes, and especially when dwelling on the remarkable knowledge, enterprise, and patient endeavor displayed in the works of the "Ancient Miners" of Lake Superior, it has not been neglected to call attention to the point that we have here to deal with a people differing essentially from the North American Indian, as we have ever known him. In discussing some of the leading facts lately revealed at Isle Royale, the identity with the Mound-builders of the men who carried out those vast undertakings to a successful issue, was deduced. It may be added that this conclusion would still seem to be the most satisfactory solution of the questions involved, and will, doubtless, become the generally received opinion, unless an unanticipated overwhelming array of opposing facts should be disclosed.

We would now present a brief summary of our later discoveries, and without unnecessarily dwelling on those to which we have already given publicity in various scientific directions, adding such inferences as seem to be naturally suggested.

The Great Mound on the River Rouge near its junction with the Detroit River, has proved a fruitful source of relics of the most valuable description. Some flattened tibiæ here exhumed by the writer first called attention to the fact of platycnemism being a characteristic of our Northern Aborigines. Up to that time, indeed, the word platycnemism (first used by Prof. Busk) had not found a place in even our scientific literature. Some of those flattened bones sent by me to the Peabody Museum at Cambridge, at once attracted the attention of the accomplished Wyman, he making them the subject of a lecture before his class at Harvard, in the winter of 1869.

But it was more than the discovery of merely this interesting peculiarity pertaining to the ancient men of our region; this flattening of the leg-bone was of a degree unheard of—I might almost say undreamt of—in any other part of this country or of the world. In many of the more extreme cases of those flattened

tibiæ with sabre-like curvature, which I had exhumed at the Rouge, the transverse diameter was only 0.48 of the antero-posterior, less than half, while in that most marked and isolated case recorded by Broca, from the cave at Cro-Magnon, France, it was 0.60. In the chimpanzee and gorilla the compression is 0.67. Shortly afterward even this extreme degree of this compression was cast in the shade by my bringing to light, from a mound on the Detroit River, rich in relics, among a number of the flattened tibiæ, two specimens of this bone in which the latitudinal indices were respectively 0.42 and 0.40. These remarkable instances were noticed in the "American Naturalist," not long subsequently, under the heading — "The flattest Tibia on record." Further, it is rare to find in the mounds mentioned, a tibia without this peculiarity, and then it is manifestly of later burial, and of less antiquity; while in other (southern) parts of the country the flattening has been estimated as pertaining to only about one-third of the mound-tibiæ.

It is worthy of note that from the same mound on the Detroit River, from which were exhumed the flattest tibiæ, were also taken several crania, of which one (though evidently adult) presented the hitherto, I think I may say, unprecedented feature of its capacity being only fifty-six cubic inches. The mean given by Morton and Meigs of the Indian cranium is eighty-four cubic inches, the minimum being sixty-nine cubic inches. This cranium forwarded with other relics to the Peabody Museum, presents (though in nowise deformed) the further peculiarity of having the ridges for the attachment of the temporal muscles only .75 of an inch apart; it in this respect resembling the cranium of the chimpanzee. It is rarely that in human crania those ridges approach each other within a distance of two inches, while they vary from that to four inches apart.

My discovering, a few years afterward, the remarkable series of tumuli at the St. Clair River and Lake Huron, farther extended the area over which platycnemic man had originally ranged. Here, though not to the extreme noted on the Detroit and Rouge Rivers, the flattening of the tibia was most decided. But for full particulars of the investigation of this important field, I must refer to the "Sixth Annual Report of the Peabody Museum of Archæology and Ethnology," or to the "American Journal of Arts and Sciences" for January, 1874, which gives nearly in full the

writer's account, with an introduction from the pen of the lamented Jeffries Wyman. This area was again further extended by my lately (1874) finding the tibiæ from an ancient mound on Chambers Island, Green Bay, marked by the peculiar flattening.

In all those mounds I find that the femora, at the upper end of the shaft, also, frequently present a compression, though to a much slighter degree than that observed in the tibiæ. The same peculiarity has been noticed by Busk in the ancient Welsh interments, a point not to be overlooked in considering this characteristic of the bone. With a few exceptions, in all the mounds, also, were found such relics as stone implements, pottery, mica, ornaments (necklaces) made of perforated teeth, shell, and small bones, as well as not unskilfully-wrought beads of copper, an implement of the same metal being occasionally exhumed.

Of the more important of our collections in this branch of science, belonging to the Detroit Scientific Association, those presented by Mr. D. F. Henry are deserving of special mention. They consist of a variety of objects obtained from the ancient mound on Chambers Island, in Green Bay, Wisconsin, and embracing the crania and other bones of man, pottery, stone implements, and a copper knife. This last object is of the pointed pattern usually found among the relics of the Mound-builders, and is formed simply by being beaten into shape, apparently without the agency of fire. Not a vestige remained of the handle, which, probably had been made of wood, and had, it is presumed, long previously decayed. Small portions of a rude sort of leather, the prepared hide of some unknown animal, adhered to the blade through the action of the oxidation, which, doubtless had also the effect of preserving those fragments. These are, unquestionably, the remnants of the sheath which once protected this (to those aboriginal men) valuable tool.

The compression of the tibia known as platycnemism, though not possessed by the Chambers Island specimens approaching to the degree which I find in my specimens from the Rouge and Detroit Rivers, and though somewhat exceeded by similar specimens which I have taken from the mounds of the St. Clair River, is yet exhibited by them slightly in excess of such bones from other (more southerly) parts of the country as given by Wyman. The last mentioned present about the flatness of the ancient bones from Denbighshire, Wales, as given by Busk, which, in turn, are much

flatter than the modern English tibiæ. The mean latitudinal index of four well-preserved tibiæ from the Chambers Island mound is .588; while their mean perimetral index (denoting the bulk or build of the bone) is .205. In nine specimens from the Detroit and Rouge Rivers the mean latitudinal index is .486; the perimetral index equalling .185; while in that extreme case from the Rouge the latitudinal index is .402.

I find, as I have elsewhere stated, that in the ancient tibiæ from our American mounds the slenderness of the bone appears to be related in some degree to the flattening; *i. e.*, the more platycnemic they are (taking the means), the more slender is the build. In individual instances, however, this does not hold good. Nor, singular to say, can it be said of the modern English tibiæ, which, perfectly exempt from this compression, are yet not so bulky as the old tibiæ from Wales, but in respect to build occupy a place between the ancient tibiæ from the Detroit and Rouge Rivers, and those from the St. Clair. Otherwise, and to judge from the American specimens which have come before me, we might conclude that platycnemism was accompanied by a reduction in the bulk of the bone, a sort of thinning out of it, if I may use the expression. As I have elsewhere considerably dilated on this peculiarity, developed in our region, as I have stated, to an extreme unknown in any other part of the world, and, in a paper printed in the Smithsonian Report for 1873, give with other matter a series of tables on this subject, which I have carefully prepared from my original observations, I must here be content with this simple reference.

It is of moment to note that I find associated with this platycnemism along the Detroit and Rouge Rivers, the perforation of the humerus. I allude to that peculiarity of the arm-bone in which is presented a communication of the two fossæ at its lower end. It is difficult to arrive at the amount of the percentage to which this prevails in these mounds; though I consider that at least fifty per cent. of the humeri are of this character. This is of interest, as being in excess of that from the mounds in other parts of the country, where it is calculated as being only 31 per cent. It is a characteristic which, significantly enough, exists in the ape, pertains to the negro in large degree, and is occasionally found in the Indian, while it is very rarely encountered in any of the white races. In a letter received last year from Prof. Busk,

F. R. S., he attaches importance to my discovery of its being a peculiarity of platycnemic man, and states that he does not think such a coincidence has been noticed elsewhere. At any rate it has not been heretofore so absolutely established. I also find in the Rouge mound transitional states, if I may so call them; that is, instances in which the communication between the fossæ is not quite completed, the dividing wall being reduced, in some cases, to a very thin partition, almost transparent. Even where the perforation is accomplished, there is a great variation in the size and shape of the aperture.

Of six crania from the Chambers Island mound, four are distinctly brachycephalic; the remaining two would fall within the orthocephalic range; but the mean of the entire number would place them under the brachycephalic category, the latitudinal or cephalic index being ·817. The mean altitudinal index is ·715, thus conforming to the rule, I think first advanced by Busk, that, in general, in all truly brachycephalic crania the former index is in excess of the latter, while the opposite may be stated in the case of dolichocephalic skulls. Deviations are found to occur in very ancient (neolithic) skulls of Europe; and an interesting exception to the rule is also seen in eight crania taken from the Great mound on the River Rouge in which I find the mean latitudinal index to be ·786, thus barely escaping being brachycephalic, and placing them within the orthocephalic range, the altitudinal index being ·802. In several individual instances, however, the rule holds good, and there is much variation between the different skulls. In respect to the mean capacity of the Chambers Island skulls, which I have ascertained approximately, they exceed but very slightly that of the crania from the Rouge; and both would fall below that of the Tasmanian, being only very little in excess of that of the Hottentot. But we must not be deceived by this. I have lately had occasion, on a similar theme, to call attention to the fact that cranial capacity must not be implicitly regarded as of physiological import. Otherwise we should have presented the anomaly of the civilized, refined Peruvian with a skull the cubic contents of which are nearly identical with those of the Australians and Hottentots, and are largely exceeded by those of the brutal North American Indian. To quote from the late Jeffries Wyman in dealing with like facts,—"Unless the quality of the brain can be represented at the same time as the quantity, brain measurement

cannot be assumed as an indication of the intellectual position of races any more than of individuals. * * * If the brains of Cuvier and Schiller were of the maximum size, so were those of three unknown individuals from the common cemeteries of Paris, while that of Dante was but slightly above the mean, and Byron's was probably even below it."

It is noteworthy that, in contrast to the modern Indian skull, and also with crania from the mounds in Kentucky and Florida, as given by Wyman, there is little indicating inferiority, or simian tendency in the position of the foramen magnum of the crania from the Chambers Island mound. Its index in the Chambers Island skulls is .422. This need not be regarded as anomalous. Those traits of a lower condition are not expected to be found associated in any one race, nor are they so found. It is well known, for instance, that in the Negro, with his general simian characteristics, the foramen magnum has nearly as forward a position as in the Caucasian.

In the Chambers Island skulls I find present an interesting deformation of this foramen, which, so far as I am aware has not hitherto been observed, and was for the first time brought to notice by me last winter (1874). I refer to an elongation of the foramen, generally in an antero-dexter and sinister-posterior direction; so that this opening partakes more or less of an elliptical form. In the crania from the Rouge mound I find either no such peculiarity, or but slight occasional indication of it.

After some speculation as to what this distortion might signify, I came to the conclusion that, in all probability, it arose from some marked habit long persisted in. And what so natural as to ascribe it to the habit associated with the method to which those primitive men resorted in capturing the animals and birds which supplied so important a part of their food? The use of the bow in hunting became with those men almost a business. All day long, and for day after day, from childhood to old age, with the majority of the males of this people this weapon was an inseparable companion. Is it too much to say that the attitude so frequently assumed in bending the bow and directing the arrow in its flight, the head thrown toward the left, has established its faithful record in the foramen magnum? This abnormal ellipticity must have some such constant cause as its origin. It would be important to note whether this deformation is to be found in other

races in which the use of the bow has predominated, and whether the habit, strengthening with succeeding generations, gradually developed and intensified the curious eccentricity. The latter, the crania from the Rouge mound, which I consider the more ancient, and in which the deformity is less marked, would apparently imply. These and a number of other enquiries suggested in connection with this peculiarity, require for their discussion and solution a large amount of material from widely separated fields of observation; and I only now allude to this peculiarity in order to draw to the subject the attention of those having the means of verifying my discovery, by noting whether it pertains to the crania in their collections.

I have prepared, from careful measurements, the series of Tables herewith presented, in which the dimensions of the crania and some of the other bones are given. Their discussion is, however, reserved for a more convenient opportunity, when I hope to be able to elucidate many points here unmentioned, or only touched *en passant*. I would add that one of the crania from the Rouge mound presents an epactal bone. This singular bone, sometimes denominated the bone of the Incas, is generally considered suggestive of Peruvian origin.

TABLE I.

DIMENSIONS, ETC., OF CRANIA EXHUMED FROM THE GREAT MOUND, RIVER ROUGE, MICHIGAN.

NO.	CAPACITY. (APPROXIMATE).[1]	CIRCUMFERENCE.	LENGTH.	BREADTH.	HEIGHT.	BREADTH OF FRONTAL.	INDEX OF BREADTH.	INDEX OF HEIGHT.	INDEX OF FORAMEN MAGNUM.	FRONTAL ARCH.	PARIETAL ARCH.	OCCIPITAL ARCH.	LONGITUDINAL ARCH.	LENGTH OF FRONTAL.	LENGTH OF PARIETAL.	LENGTH OF OCCIPITAL.	ZYGOMATIC DIAMETER.
1.[2]	18.65	19.00	7.30	6.00	5.35	4.02	.832	.733	.465	12.15	12.00	11.65	14.00	5.50	4.40	4.10	—
2.[3]	18.10	19.50	7.30	5.20	5.60	3.60	.712	.767	.547	11.80	12.75	11.50	15.35	4.95	5.50	4.90	4.20
3.	18.00	19.50	7.00	5.40	5.60	3.95	.777	.800	.500	12.65	12.20	10.30	14.60	5.00	4.75	4.85	—
4.	18.47	—	7.20	5.40	5.77	4.07	.763	.801	.479	12.10	12.00	11.10	13.45	4.75	5.40	4.30	—
5.[4]	16.54	18.50	6.90	4.70	4.94	3.74	.681	.716	—	11.20	10.25	11.30	13.95	4.50	4.75	4.70	5.00
6.[5]	18.23	22.40	6.80	5.80	5.63	4.63	.853	.828	.397	11.10	13.15	11.00	14.85	5.40	4.60	4.85	5.60
7.[6]	18.82	—	7.60	5.62	5.60	4.01	.739	.736	.473	11.50	—	—	—	5.10	—	—	—
8.	15.93	18.00	5.35	5.03	5.55	4.08	.940	1.037	.605	11.90	12.80	11.30	13.90	4.90	4.90	4.10	—
Means.	17.84	19.48	6.93	5.40	5.50	4.01	.786	.802	.495	11.80	12.16	11.16	14.30	5.01	4.90	4.54	4.93

NOTE:—The fragments of a cranium, consisting chiefly of a very retreating frontal, and presenting traits of a low and brutal character, reminding one of the Neanderthal Skull, were found underneath the above tabulated crania.

[1] Opportunity did not permit to obtain the exact (absolute) capacity. [2] Artificially perforated. [3] Very retreating frontal.

[4] Very protuberant occipital. [5] Artificially perforated.

[6] With epactal bone 1.5 in length. It may be interesting to mention that I find occasionally in our mounds a tendency to the formation of the epactal bone by a sudden approach of the sutures immediately below the apex of the occipital—a sort of transitional state.

TABLE II.

DIMENSIONS, ETC., OF CRANIA FROM ANCIENT MOUND, CHAMBERS ISLAND, GREEN BAY, WISCONSIN.

No.	Capacity (approximate.)[1]	Circumference.	Length.	Breadth.	Height.	Breadth of frontal.	Index of breadth.	Index of height.	Index of foramen magnum.	Frontal arch.	Parietal arch.	Occipital arch.	Longitudinal arch.	Length of frontal.	Length of parietal.	Length of occipital.	Zygomatic diameter.
1.[2]	17.85	20.25	6.90	5.75	5.20	4.20	.841	.771	.367	12.25	13.75	11.00	14.40	5.30	4.20	4.90	—
2.	17.36	21.00	7.28	5.68	5.40	4.33	.780	.742	.464	11.50	13.00	11.75	14.60	5.20	4.20	5.20	5.74
3.	17.50	20.37	7.08	5.65	4.77	3.74	.798	.673	—	11.20	13.50	10.00	13.90	5.00	4.60	4.30	4.64
4.[3]	18.29	20.50	7.17	6.00	5.12	4.29	.836	.714	.376	11.50	12.75	11.50	14.60	5.10	4.50	5.00	—
5.	18 56	20.75	7.00	6.06	5.50	4.38	.865	.785	.481	12.30	13.40	11.20	13.95	5.00	4.75	4.20	5.75
6.	17.80	21.45	7.45	5.85	4.50	4.20	.785	.604	—	12.30	13.90	11.00	—	5.60	5.10	—	—
Means.	17.89	20.72	7.14	5.83	5.08	4.19	.817	.715	.422	11.80	13.26	11.07	14.29	5.20	4.55	4.75	5.37

NOTE:—I have dilated elsewhere on the supposed age of this mound, which was partly overgrown with the remains of an old growth of forest.

[1] Opportunity did not permit to obtain the exact (absolute) capacity. [2] Old. [3] Old.

Before dismissing the crania, however, I wish to notice what seems to me to betoken a singular practice connected with the burial ceremonies of the aboriginal inhabitants of this country, and of which I can find nothing on record in the books, notwithstanding the remarkable nature of the custom, and the indubitable marks which would remain to testify in instances where it had been adhered to. I have reference to the artificial perforation of the top of the skull after death.

The circular aperture, evidently made by boring with a rude, probably stone, implement, varies in size, in some skulls having a diameter of one-third, in others one-half of an inch, or more, and flaring or being bevelled at the surface. It is invariably placed in a central position, at the top of the head.

The first instance of its being brought to my knowledge was in the year 1869, when I took from the Great Mound on the River Rouge two fragments of crania, each of which exhibited this perforation. A skull recently presented to the Detroit Museum by Mr. Davis, and which was exhumed from a mound on the Sâble River, Lake Huron, Michigan, also has this mark. From ten to fifteen skulls were taken from the same mound, all being similarly perforated, and there being, as I am informed, no other remains interred with them. During the summer of 1874, in some further excavations made in the Great Mound at the River Rouge, Michigan, among other relics exhumed were eight crania, two of which had this aperture. (See Figs. 1, 2, 3 and 4). Of the remaining bones belonging with the two skulls in question, I specially noticed that many were wanting, and that those present were heaped *en masse*, and not in the usual manner of burial, seeming to imply that they were interred subsequently to being denuded of the flesh and other soft parts of the body.

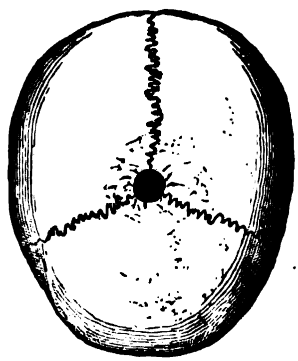


FIG. 1. Artificially perforated Skull(No. 1)from the Great Mound, River Rouge, Michigan. ½ size.

Besides the foregoing instances of this curious custom which have been brought immediately to my knowledge, I have since been informed of a skull having been found at Saginaw, Michigan,

which presented the peculiarity; but in this case there were three perforations arranged cocoa-nut fashion. For a more extended

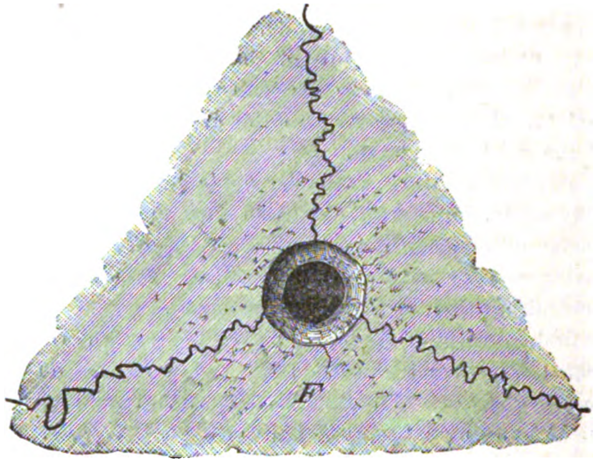


Fig. 2. Artificial perforation of Skull No. 1 from the Great Mound, River Rouge, Michigan. Full size. F, frontal.

notice of these perforated skulls see the "American Naturalist" for August, 1875.

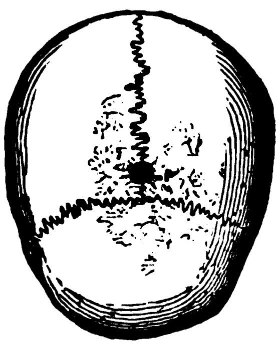


Fig. 3. Artificially perforated Skull (No. 6) from the Great Mound, River Rouge, Michigan. ½ size.

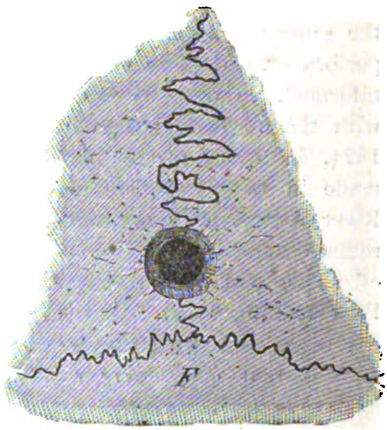


Fig. 4. Artificial perforation of Skull No. 6, from the Great Mound, River Rouge, Michigan. Full size. F, frontal.

The skull from the Sâble River mound (Figs. 5 and 6) is of a dark color; and its latitudinal or cephalic index, .770, would place

it within the orthocephalic or medium range; the altitudinal index being inferior, or exactly .745. The foramen magnum approaches a central position, its index being .445. The two perfect specimens from the River Rouge are decidedly brachycephalic, the cephalic indices being respectively .822 and .853, the altitudinal indices being inferior, or respectively .733 and .828, while the indices of the foramen magnum are, in the first instance .465, and in the second .397.

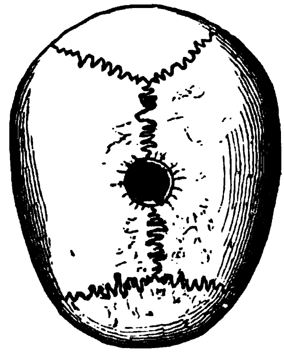


FIG. 5. Artificially perforated Skull from Mound at Sâble River (Lake Huron) Michigan. ½ size.

It is to be hoped that in thus calling attention to this singular custom, further information will be elicited; and I take this opportunity of earnestly soliciting the communication of any facts bearing on the subject.[1]

In resuming the excavation of the Great Mound at the River Rouge, the opening was made at what was presumed to be its original centre. At the depth of three feet, human bones, much decayed (though including the eight nearly perfect crania, already mentioned), with fragments of pottery and a few stone implements were exhumed. At four feet deep occurred abundant evidence of cremation in the presence of masses of burnt human remains and ashes with charcoal — compact, discolored agglomerations, separated from each other by the surrounding pure sand of the mound. The average bulk of those spheroidal bodies, in which fragments of burnt bone abounded, gave a length of two feet, a breadth of one and one-half feet, and a height of one and one-quarter feet. Beneath those peculiar interments which had remained undisturbed, nothing but sand was encountered for four feet additional depth, or a total of eight feet from the surface. At this depth white lime-like masses, each of a few inches in circumference, were reached. They had little resemblance to bone, though subsequent examination proved them to be such, and of man. In a few cases the remains of the exfoliated cellular tissue were quite apparent, while the outlines of portions of some of the principal bones

[1] Figs. 7 and 8 present an additional instance of this artificial perforation, in a skull from a mound on Devil River, Michigan.

could be sufficiently recognized to determine whether they belonged to femur, tibia, fibula, humerus or ulna. But in the majority of instances, those remains of our brother man (of which there were considerable quantities) had returned to "dying Nature's earth and lime"—had obeyed the infinite decree: "Dust thou art, and

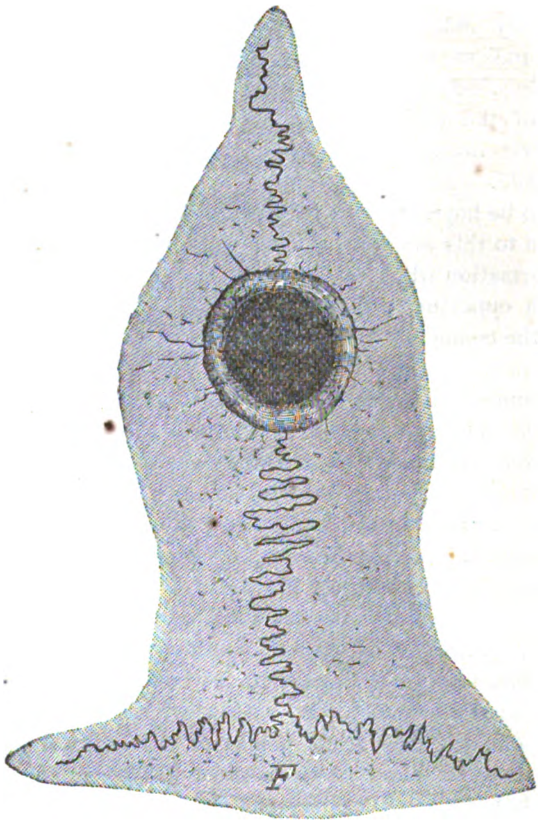


Fig. 6. Artificial perforation of Skull from Mound at Sâble River, Michigan. Full size. F, frontal.

unto dust shalt thou return." These, in general ball-like masses continued to the depth of ten and one-half feet, where operations were suspended.

Over the greater part of what is left of this mound, at about eighteen inches from the present surface, occurs an almost continuous bed or stratum of burnt bones and ashes with intermingled

fragments of pottery. I have already (in 1869 and subsequently) called attention to the evidences of the practice of cremation in the burials here, and it is unnecessary that I should at present dwell on the subject. It must be borne in mind that this mound

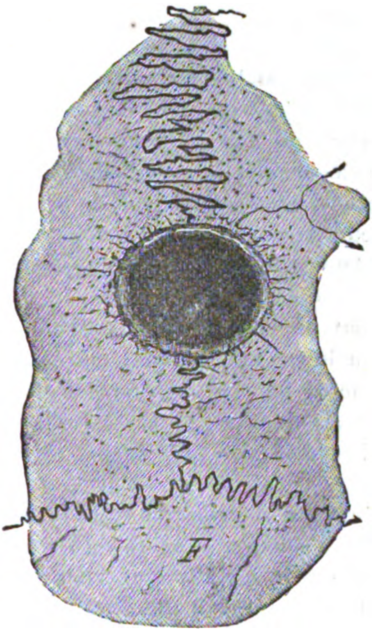


FIG. 8. Artificial perforation of Skull from Mound at Devil River, Michigan. Full size. F, frontal.

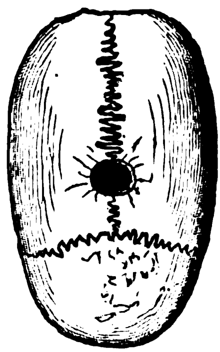


FIG. 7. Artificially perforated Skull from Mound at Devil River (Lake Huron), Michigan. ½ size.

has been much disturbed, and large quantities of the sand, its chief component, removed.

The indications of the presence of a former race are abundant in the vicinity. An ancient "Enclosure" on the Detroit River, immediately below Fort Wayne, and pointed out by Mr. Hubbard, is an interesting example of this. The general outline of the plan is an irregular ellipse, the greater diameter being 320 feet, and running slightly West of North and East of South, or nearly at right angles to the direction of the river, the less diameter being 250 feet in length. The unequally defined embankment is but three feet high where best preserved, having a width at base of twelve feet, and is surrounded by a ditch-like depression about

eight feet wide. Oak trees of one and one-half feet in diameter are now growing at several points of the embankment. In an oak tree which had been felled thirty-six annual rings were counted. These trees appear to be of the "second growth." I understand that this "enclosure" was known to the early white settlers before the original forest had been destroyed.

Mr. Davis and the writer have presented to the Detroit Museum specimens of the massive stone mauls and other relics from the recently discovered "Ancient Mining" pits on Isle Royale, Lake Superior. Such remarkable discoveries and of such immediate interest, as have there been made, cannot be overlooked in an account such as this; but for details, respectful reference is made to the paper, by the writer, entitled "Ancient works at Isle Royale," printed in Appleton's Journal, August 9, 1873, and to the paper printed in the Smithsonian Report for 1873.

I cannot close, however, without expressing my wondering admiration of a relic, which, taken in connection with our former discoveries, affords some of the most important evidences of the character of the "Ancient Miners," the nature of their work, and the richness of the mineral field selected for their labors at Isle Royale.

Late last autumn, there was brought to our city a mass of copper which, in the latter part of the summer, was taken from an ancient pit on the property of the Minong Mining Company, at McCargo's Cove, Isle Royale. On cleaning out the pit of the accumulated *débris*, this mass was found at the bottom, at the depth of sixteen and one-half feet. It is of a crescent-like shape, and weighs nearly three tons, or exactly 5,720 pounds. Such a huge mass it was evidently beyond the ability of those ancient men to remove. They could only deal with it as best they knew how. And as to their mode of procedure, the surroundings in the pit and the corrugated surface of the mass itself bear ample testimony. The large quantities of ashes and charcoal lying around it, show that the action of fire had been brought to bear on it. A great number of the stone hammers or mauls were also found near by, many of them fractured from use. With these the surface of the mass had evidently been beaten up into projecting ridges, and then broken off. The entire upper face and sides of the relic present repeated instances of this; the depressions, several

inches deep, and the intervening elevations with their fractured summits, covering every foot of the exposed superficies.

How much of the original mass was removed in the manner described, it is, of course, impossible to say. But from appearances, in all probability, it had, at least, been one-third larger. Innumerable fragments of copper chips lay strewn on all sides; and even the scales of fish, evidently the remnants of the meals of the miners, were recovered from the pit.

TITLES OF COMMUNICATIONS.

The following titles of papers read in Section B include those accepted by the committee for publication in full, or by abstract, but of which the authors have failed to send copy, as well as those which the committee decided should be printed by title only:

A Remarkable Glacial or Drift Deposit in Johnson County, Indiana. By D. R. Malone, of Edinburg, Ind.

Notice and Exhibition of some Prehistoric Remains from Michigan and Illinois. By A. Winchell, of Syracuse, N. Y.

The Relations of Insects to Flowers. By W. J. Beal, of Lansing, Mich.

Additional Observations on the Tarsus and Carpus of Birds. By Edw. S. Morse, of Salem, Mass.

On the Galisteo Sandstone of New Mexico. By E. D. Cope, of Haddonfield, N. J.

Contribution to the Archæology of New Mexico. By E. D. Cope, of Haddonfield, N. J.

Kaoline Beds of Southern Illinois. By H. C. Freeman, of Cobden, Ill.

Indications of Descent exhibited by North American Tertiary Mammalia. By E. D. Cope, of Haddonfield, N. J.

On some new Fossil Fishes and their Zoological Relations. By J. S. Newberry, of Cleveland, Ohio.

On some of the Results of the Geological Survey of Ohio. By J. S. Newberry, of Cleveland, Ohio.

The Ice Period in the Mississippi Valley; its phenomena and causes. By J. S. Newberry, of Cleveland, Ohio.

ON ANCIENT GLACIATION AT KELLEY'S ISLAND, OHIO. By CHAS. WHITTLESEY, of Cleveland, Ohio.

ANCIENT EARTHWORKS NEAR ANDERSON, INDIANA. By E. T. COX, of Indianapolis, Ind.

INDIANANITE, A NEW FORM OF KAOLIN FOUND IN INDIANA. By E. T. Cox, of Indianapolis, Ind.

AMERICAN ANTIQUITIES. By C. C. CUSICK, LIEUTENANT U. S. Army.

AZTEC CONFEDERACY. By L. H. MORGAN, of Rochester, N. Y.

THE GRASSES OF THE PLAINS AND THE ROCKY MOUNTAIN DISTRICT. No "GREAT AMERICAN DESERT." By WILLIAM BROSS, of Chicago, Ill.

ON THE SUPPOSED ANCIENT OUTLET OF GREAT SALT LAKE. By A. S. PACKARD, Jr., of Salem, Mass.

ON THE GESTATION OF BATS. By B. G. WILDER, of Ithaca, N. Y.

THE AFFINITIES AND ANCESTRY OF THE EXISTING SIRENIA. By B. G. WILDER, of Ithaca, N. Y.

NOTES ON MENOBRANCHUS AND MENOPOMA. By B. G. WILDER, of Ithaca, N. Y.

ON THE STRUCTURE AND ECONOMY OF LAMPREY EELS (*Petromyzon*). By B. G. WILDER, of Ithaca, N. Y.

THE RECTAL POUCH OF SHARKS AND SKATES, AS PERHAPS REPRESENTING THE ALLANTOIS OF AIR BREATHING VERTEBRATES. By B. G. WILDER, of Ithaca, N. Y.

NOTE ON A COLT WITHOUT FRONT LEGS; AND ON A CHICKEN WHICH WAS DEVELOPED WITHIN THE HEN. By B. G. WILDER, of Ithaca, N. Y.

THE NEED OF A MUSEUM EXCHANGE FOR SPECIMENS OF NATURAL HISTORY, SIMILAR TO THE NATURALISTS' AGENCY FOR BOOKS. By B. G. WILDER, of Ithaca, N. Y.

EXHIBITION OF SOME CURIOUS DISKS OF SILICA IN THE STRUCTURE OF COAL FROM TENNESSEE. By J. LAWRENCE SMITH, of Louisville, Ky.

ON THE FISHES OF THE CRETACEOUS BEDS OF KANSAS. By E. D. COPE, of Haddonfield, N. J.

RATIO OF HUMAN PROGRESS. By L. H. MORGAN, of Rochester, N. Y.

NOTES ON ABORIGINAL MONEY OF CALIFORNIA. By LORENZO G. YATES, of Centreville, Cal.

NOTES ON THE GEOLOGY AND PHYSICAL GEOGRAPHY ABOUT THE HEAD WATERS OF THE MISSOURI, COLUMBIA AND COLORADO RIVERS IN WYOMING TERRITORY. By T. B. COMSTOCK, of Ithaca, N. Y.

EXECUTIVE PROCEEDINGS

OF

THE DETROIT MEETING.

HISTORY OF THE MEETING.

THE TWENTY-FOURTH MEETING of the American Association for the Advancement of Science was held at Detroit, Michigan. The meeting was called to order at 10 o'clock on Wednesday, the eleventh day of August, 1875, and was closed in General Session on the Tuesday night following.

With the exception of the closing night, the General Sessions were held in the commodious Opera House. This building was also used for the Sessions of Section B, excepting Thursday, when the Section met in the Recorder's Court Room in the City Hall. On Tuesday night the closing General Session was held in the Circuit Court Room in the City Hall.

Section A was assigned to the Circuit Court Room where it was well accommodated, and continued in session until Monday evening, when, all the papers having been read, it adjourned.

The Permanent Subsection of Chemistry held its sessions in the Common Council Chamber, City Hall. This subsection did not have any session on Saturday and finished its work on Monday evening.

Section B was subdivided on Tuesday.

The Subsection of Biology continued in the Opera House until Tuesday evening, when it concluded its sessions, and the Subsection of Geology occupied the Circuit Court Room for the day, also adjourning on Tuesday evening.

The Citizens of Detroit had not only placed the Opera House and the several rooms mentioned in the City Hall at the disposal of the Association but a number of other rooms in the City building as well. Of these, the Controller's room formed a convenient, though rather small, Local Committee reception room, post and telegraph office, with the office for the Permanent Secretary adjoining. The Standing Committee were well provided with the Committee Room of the Common Council, and several other rooms were ready in case the sections should subdivide. Temporary use was made of these by Committees and for informal meetings.

The Proprietor of the Biddle House, Mr. J. M. Maxwell, in addition to other acts of courtesy, placed two parlors at the disposal of the members during the period of the meeting, and, as a large number of the members were quartered at this hotel, Committee Meetings were almost daily and nightly held at the hotel.

Altogether the meeting was well provided for as to accommodations, and the Association is much indebted to the citizens of Detroit, and especially to the members of the Local Committee and the proprietors of the Opera House for their efforts and thoughtful arrangements. The only drawback was the distance between the several places, but there are very few cities where the proper accommodation for the meeting can be had in one building, and it can only be expected that the Local Committees will secure the several rooms required at the least distance apart that may be possible, as was done at Detroit.

Two hundred and eighty-eight tickets were given out for the meeting, but only one hundred and sixty-five members and fellows signed the register at Detroit.

Ninety-five members were elected. Of these fifteen have not yet replied to the two notices that have been sent.

Two life members were added to the list. The name of Mr. Elwyn, for many years the Treasurer of the Association, was placed on the list by the vote of the Standing Committee, as a slight acknowledgment of the services which he had rendered the Association in its early years. One hundred and nineteen members were elected fellows, three of whom have declined, and ten have not yet complied with the requirements of the Constitution in relation to fellowship, and consequently their names are not yet entered in the list.

Of the thirty-two members of the Standing Committee eighteen were present.

Notice was given of the decease of six members since the last meeting.

The comparative small attendance of members at Detroit was evidently due in great measure to the several causes noticed by the President in his closing remarks, and from extensive correspondence since the meeting it is evident that the general financial depression in the country at the time of the meeting, added to the apparent lack of concessions on the part of the railroads, prevented a large number of members from taking part in the meeting.

One hundred and thirty-six papers were entered by title on the general list. Of these two were not considered by the Standing Committee as their authors failed to furnish the required abstracts; three were withdrawn by their authors and twelve were declined by the Standing and Sectional Committees. Of the remaining one hundred and nineteen, two were read in General Session in full and two by title; one was given as a popular evening lecture; forty-four were read in Section A, nineteen in the Chemical Subsection, and seventy in Section B, including its subsections formed towards the close of the meeting. Of the one hundred and eighteen papers thus brought before the regular sessions, sixty-five were

accepted for printing in full, thirty-three in abstract, and twenty by title. Of the ninety-eight papers accepted for the volume the authors have failed in thirty-eight instances to send their manuscripts for publication, hence these papers are only given in the volume in the lists of titles of papers read. Notices were sent on September 8th to all authors whose accepted papers had not been received at that date.

The Standing Committee having made but a very small appropriation for illustrations for the present volume, it is necessary for me to state that the Association is indebted to the following gentlemen for the illustrations accompanying their papers:—Dr. Hilgard, Mr. Osborn, Prof. Mendenhall, Mr. Stevens, Dr. Dawson, Prof. Barnard, and Dr. Wilder. Col. Whittlesey also furnished the woodcuts in his article, and President Hilgard kindly provided the map for the same. It is also to President Hilgard that the Association is indebted for the two fine lithographic plates illustrating Dr. Farquaharson's paper, while the other four plates accompanying the last mentioned paper were obtained by an exchange of copies of plates one and two with the Davenport Academy of Science. Prof. Henry has kindly allowed the use of the woodcuts in Mr. Gillman's paper in advance from the Annual Report of the Smithsonian Institution.

The address of the Retiring President, Dr. LeConte, was delivered in General Session, at the Opera House on Thursday evening, and those of the Vice Presidents, Prof. Newton and Dr. Dawson in General Session on the following morning.

Consent having been granted in Section B, a Permanent Subsection of Anthropology was organized for the next meeting by the election of Hon. Lewis H. Morgan as Chairman, and the appointment of a committee to further the interests of the Subsection at the next meeting.

Informal action was taken by a number of members specially interested in Microscopy, in favor of the formation, at the next meeting, of a Subsection, or an Association Club similar to that of the Entomologists.

The Entomological Club of the Association, held several sessions during the week.

The very active interest taken by a number of the citizens of Detroit, especially by the members of the Local Committee, and the Detroit Scientific Association, resulted in making the meeting very agreeable in its social aspects, as well as adding to its scientific success by the attentions bestowed and the readiness with which desired assistance was granted.

The evening reception given on Wednesday by the members of the Detroit Scientific Association, at their Museum, was very interesting and cordial, while the following receptions on Thursday, Friday and Monday evenings by Governor Bagley, Mr. and Mrs. E. A. Brush, and Mr. and Mrs. A. W. Leggett, added much to the social enjoyment of the members and, it is hoped, proved equally agreeable to the citizens and generous hosts on the several occasions.

Saturday afternoon was devoted to a delightful excursion on the Detroit River, given by the Citizens of Detroit, under the direction of the

Local Committee on Excursions, to the members of the Association and invited guests. The Steamers "Victoria" and "Fortune" were lashed together, most comfortably accommodating about eight hundred ladies and gentlemen who joined in the excursion. A short trip up the river was first taken, and then, turning, the boats passed by the city and below nearly to Stony Island, when the boats were turned homeward, but on the way a landing was made at the Alexander House wharf and time allowed for a pleasant stroll about Grosse Isle. The party arriving safely at Detroit about 8 o'clock in the evening. The varied scenery along the river, including glimpses of the ancient mound and earthwork on its bank, was much enjoyed, while the bountiful collation, the music by the band of the 22d Reg. of Infantry, provided by the courtesy of the Commanding Officer of Fort Wayne, and by the orchestra of stringed instruments, all combined to make the excursion a charming episode of the Detroit meeting.

The numerous invitations extended to the Association by the several large manufacturing and smelting companies of Detroit and vicinity, and by the several societies and State Institutions, as well as by individuals, were quite generally accepted by small parties at various times.

At the invitation of Mr. N. G. Clark and the citizens of Northville two parties, one after the close of the meeting, visited the famous fish breeding establishment of Mr. Clark, where they were intellectually entertained, and hospitably received, by Mr. Clark and the citizens of the place.

For further information in relation to the meeting reference is made to the following Report of the General Secretary.

F. W. PUTNAM,

Permanent Secretary.

REPORT OF THE GENERAL SECRETARY.

THE ASSOCIATION met at the Opera House, Detroit, at 10 A. M. on Wednesday, August 11, 1875, and was called to order by the retiring President, Dr. JOHN L. LECONTE, who introduced the President elect, Dr. JULIUS E. HILGARD. After prayer by the Rev. Dr. WILLIAM AIKMAN, the Hon. C. I. WALKER, on behalf of the DETROIT SCIENTIFIC ASSOCIATION, delivered the following address of welcome:

GENTLEMEN OF THE NATIONAL ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: In behalf of the Scientific Association of Detroit, and of our citizens generally, I give you a most cordial welcome to the City of the Straits.

We can boast of no great achievements in scientific research and discovery, we can point to no one who by his labors in this field has placed himself among "the few immortal names that were not born to die;" but you will remember that it is less than forty years since Michigan became a sovereign State, and we have been too busy in bringing wild nature into subjection to man, in subduing the forest, in making the wilderness to blossom as the rose, to give very much attention to science, except in its most rudimental phases, and as directly and practically connected with those industries that predominate in a new State. And yet we claim that we have not for half a century been drawing from the population and culture of the East and of the old world in vain. Where in any new country (I might almost say where in any country) will you find a better system of public schools, and a nobler university? These have aided in sowing broadly and planting deeply a taste for higher culture, and the seed is germinating and will, we trust, come both to flower and fruitage.

Many of you, perhaps most of you, come from the older States. You are upon the confines of the old Northwestern Territory, now comprising the great States of Ohio, Indiana, Illinois, Michigan and Wisconsin. In this centennial period it may not be inappropriate to recall to your memory the actual condition of this Territory one hundred years ago to-day. There was not a settlement of English origin within this whole Territory. The entire population did not probably exceed 5,000. At the close of the old French and Indian war in 1763, that resulted in the conquest of Canada by Great Britain, and the surrender of this whole region, as far west as the Mississippi to British control, there was probably a French population of about 10,000. But so deeply dissatisfied were they at the change that they, in large numbers, emigrated to the lower Mississippi, which was still under French control. In 1764 Laclede founded St. Louis, and many went thither. So great was this change that the Detroit settlement was reduced from a population of 2,500 to about 800, and Kaskaskia from 1,500 or 2,000 to about 500.

At this time, 1775, Detroit, the most important town, occupied about three acres upon the bank of the river, inclosed by pickets from fifteen to twenty-five feet high, which were pierced by four gates, defended by

blockhouses and guns. It was traversed by narrow streets or alleys from ten to sixteen feet in width. There were from eighty to one hundred dwellings, all of logs, except the house of the commandant. It contained a population of from 300 to 400. Of these thirty were Scotchmen, fifteen Irishmen and two Englishmen, mostly traders who were new comers and without families. The rest were French. The old fort erected at the settlement in 1701 had gone to decay. Scattered up and down the river near the town was a French population of from 300 to 400 more.

During the revolution Detroit was the seat of British power in the Northwest. From her emanated those bloody Indian forays that carried terror and devastation to the border settlements of Pennsylvania, Virginia and Kentucky. Here the famous Kentucky partisan, Daniel Boone, was brought as a prisoner by his Indian captors. From here went out Governor Hamilton with a proud force of British and Indians to capture George Roger Clark, and was himself captured at Vincennes by that gallant officer.

Next to Detroit in importance was Mackinaw with its fort, thirty families within the pickets, and a still larger number in the vicinity. There were small stockade forts at Sault St. Mary and on the St. Joseph River, with a few French families around each.

In the great State of Ohio was not a single settlement, unless the Moravian Mission on the Newburgh be so termed. Sandusky had been occupied temporarily as a military post, but it was not a permanent one and had no settlement. In Indiana there were but three small settlements, of which Vincennes was the principal. In Illinois there were several settlements, of which Kaskaskia and Cahokia were the principal. In Wisconsin there was only one small settlement at Green Bay, protected by a stockade fort.

These were all the settlements in this great Northwest at the commencement of the Revolution, and, as I have said, the population did not probably exceed 5,000, and these were largely engaged in the fur trade. The strictly agricultural population was very small. Yet scattered through these primeval forests and running over these prairies there was a population neither to be ignored nor despised. Sir William Johnson, than whom there is no better authority, estimated the number of Indian warriors in the Territory at 8,990.

This Territory, whose condition a century since I have thus described to you, now composes the five great States named, with a population of 10,000,000, and is rich with the production of human industry and human art.

No other section of the Union of the same area comprises so many advantages, or is capable of sustaining so dense a population. With scenery of great and diversified beauty, a climate varied and delightful, a soil of surpassing richness and fertility, sustaining a wealth of timber that the energies of man cannot destroy for generations to come, with exhaustless mines of lead, iron, coal, copper and salt, and traversed and environed by noble rivers and great lakes, the equal of which are not to

be found upon the face of the earth, it is not surprising that its growth in population and wealth is without a parallel in the history of the world.

In the light of the present state of things it is not without interest that we read a description and prediction made in the Parliament of Great Britain in 1791. Detroit and its dependencies, including Wisconsin, remained in the possession of Great Britain until after Jay's treaty of 1794, and thus was practically a part of Canada. In 1791, when the act dividing the District of Quebec into Upper and Lower Canada was under discussion in Parliament, a leading merchant of Quebec, Mr. Lyneburner, was heard in opposition to the act. He contended that "Niagara was the utmost extent westward of the cultivable part of the province," that while it was true that there was a small settlement at Detroit, and it was of great importance as a post for the Indian trade, it could never become of great importance as a place of settlement; that the falls of Niagara presented a barrier to the transportation of produce, which must greatly impede the progress of settlement and cultivation for ages to come.

It is to this Detroit, this Northwest, to which we welcome you in this year of our Lord 1875. Witness for yourselves how far this prediction has become history. I trust that your visit here will be as pleasant to you as it certainly will be to us, and profitable to us all.

In the great future that lies before us to mature we need a complete and harmonious development, both of our material resources and intellectual and moral powers and faculties. Such associations as this, such labors as yours, have an important place in this development, and we bid you a hearty God-speed.

President HILGARD replied as follows:—

In behalf of the American Association for the Advancement of Science I return thanks to the Detroit Scientific Association and to the citizens of Detroit for their cordial welcome, and to you, sir, for the kind and eloquent words in which it has been expressed. The arrangements made for the convenience, comfort and entertainment of the members of this Association by your generous kindness are a fit sequel to the cordial invitations received by us last year at Hartford from your city authorities, your Governor, your scientific and literary societies, and from the University of Michigan.

That invitation was the more welcome as it seemed desirable that the meeting should be held somewhere in the heart of our great country, in order to facilitate the attendance of those members who, living in the West, are in a measure isolated and restricted in their intercourse with men of similar pursuits.

The growth of sympathy and brotherhood, fostered by personal contact and oral exchange of views, is one of the most valuable elements in our annual reunions. Another is the awakening of a more lively interest in science in the communities where the meetings are held.

Local institutions are strengthened by an increased sympathy with their objects, and new recruits are enlisted from the ranks of the young—the young, in whom lie all hopes of the future.

You have referred, sir, to the brief time within which your Commonwealth has grown to its present condition, in explanation of the preponderance of material interests heretofore and of the disparity in the development of scientific interests as compared with older communities. But when we look at the grand organization at work in this State for the higher education of the people, we may rest assured that in less than two generations that disparity will have disappeared, for the boys and girls who are receiving the higher culture of the present day at your universities will feel the delight of seeking out the ways of the Creator, and of advancing step by step in the comprehension of the laws he has impressed upon nature.

Again, let us thank you for your kind welcome.

The General Secretary, Mr. SAMUEL H. SCUDDER, read the names of forty persons recommended for membership by the Standing Committee, and they were elected.

Invitations were read from the Young Men's Society, the Detroit Gas Light Company, and the Superintendent of the House of Correction, and referred to the Standing Committee.

A letter was also read from the Secretary elect of Section B, Prof. N. S. SHALER, regretting his inability to attend the meeting.

The Permanent Secretary, Mr. F. W. PUTNAM, announced the decease of six members during the year: — JOHN E. GAVIT of New York, Dr. THEODORE C. HILGARD of St. Louis, Prof. JOSEPH WINLOCK, Director of the Observatory of Harvard College, Sir WILLIAM E. LOGAN of Canada, Prof. JEFFRIES WYMAN of Harvard College, and WILLIAM E. WHITMAN of Philadelphia.

The General Secretary read a list of seventy-six members proposed for fellowship by the Standing Committee, and they were elected.

The Association then elected Professors E. S. MORSE, E. B. ELLIOTT, E. T. COX, G. J. BRUSH, G. F. BARKER and S. W. JOHNSON members-at-large of the Standing Committee.

Prof. A. WINCHELL, whose name had been omitted from the list of nominees for this office, because it did not appear upon the printed list of fellows, explained that he had indicated a year previously, in a letter to the Permanent Secretary, his desire to become a fellow in accordance with the last clause of the fourth section of the constitution; but that the Secretary appeared not to have received the letter. Whereupon it was voted that Professor Winchell's explanation be accepted and his name placed upon the list of fellows.

The recommendation of the Standing Committee that the daily recess should extend from 12.30 to 2.30 P. M. was adopted.

In the afternoon the Association met in sections.

SECTION A met in the Circuit Court Room, City Hall, and was called to order by Vice President Prof. A. H. NEWTON of Yale College, the Secretary, Prof. S. P. LANGLEY of Allegheny, Pennsylvania, in attendance.

Professors G. F. BARKER, T. C. MENDENHALL and W. H. CHANDLER were chosen members of the *Sectional Committee.*

SECTION B met in the Opera House, and was called to order by Vice President, Principal J. W. DAWSON. The Secretary, Professor N. S. SHALER, being absent, Professor E. S. MORSE was chosen to fill his place, and Professor E. D. COPE, Rev. J. G. MORRIS and Professor C. V. RILEY were elected as a *Sectional Committee.*

THE PERMANENT SUBSECTION OF CHEMISTRY met in the Common Council Chamber, City Hall, and was called to order by the Chairman, Professor S. W. JOHNSON of Yale College. Professor F. W. CLARKE of Cincinnati was chosen Secretary.

The Second Day's session was opened in the Opera House at 10 A. M.

The General Secretary read the names of twenty-three persons recommended to membership by the Standing Committee and they were elected.

Professor E. S. MORSE having been elected Secretary of Section B, resigned his position as member-at-large of the Standing Committee, and Professor F. W. CLARKE was chosen in his place.

Invitations received from the Wyandotte Silver Smelting Works, and the Detroit and Lake Superior Copper Smelting Works, were referred to the Standing Committee.

The General Sessions then adjourned, and the Sections immediately assembled for the reading of papers.

In SECTION A., Messrs. G. W. HOUGH of Albany, H. T. EDDY of Cincinnati, H. C. BOLTON of New York, and J. N. STOCKWELL of Cleaveland; and in SECTION B, Messrs. A. R. GROTE of Buffalo, A. H. TUTTLE of Columbus, E. D. Cope, of Philadelphia, and L. H. MORGAN of Rochester, were elected members of the Nominating Committee.

At 8 P. M. the address of the retiring President, Dr. J. L. LECONTE, was delivered before the Association, in General Session, at the Opera House.

The Third Day's session was held in the Opera House, commencing at 10 o'clock.

The General Secretary read a list of eleven persons recommended to membership by the Standing Committee and they were duly elected.

The following resolution offered at the instance of the Entomological Club of the Association, and recommended for passage by the Standing Committee was adopted:

Resolved:—That the Association earnestly request the State authorities of the different States of the Union, as well as the officers in the respective departments of the National Government to furnish the library of the Association with all their printed reports upon scientific subjects, by remitting them to the Permanent Secretary.

Invitations received to visit the Fish Breeding establishment at Northville, the Detroit Stove Works, the Detroit Locomotive Works, and two paintings by the late Mr. J. M. Stanley, were referred to the Standing Committee.

The Permanent Secretary announced, on behalf of the Committee on the ELIZABETH THOMPSON DONATION, that the entire sum had been expended in the publication of a quarto memoir on Fossil Butterflies, of one hundred pages and three plates, by Mr. S. H. Scudder.

The Association then listened to the addresses of Professor H. A. NEWTON and Dr. J. W. DAWSON, Vice Presidents of Sections A and B.

The General Secretary read the following invitations which had been received for the meeting in 1876 from Nashville, Philadelphia and Buffalo.

DEPARTMENT OF PUBLIC INSTRUCTION.

OFFICE OF THE STATE SUPERINTENDENT,
NASHVILLE, TENN., AUGUST 6, 1875.

WHEREAS, At the Meeting of the American Association for the Advancement of Science held at Newport, August, 1860, an invitation was accepted to hold its next annual meeting at Nashville, Tennessee; and whereas said meeting was prevented from being held by hindrances of Civil War, now then, we the undersigned, citizens of Nashville and of Tennessee, do respectfully and cordially invite the said great National Association to hold its next meeting in the Capitol of Tennessee. We pledge our earnest endeavors to make the meeting here in every way a success.

Signed by:
JAS. D. PORTER, *Governor of Tennessee.*
CHAS. N. GIBBS, *Secretary of State.*
JAS. L. GAINES, *Comptroler.*
W. MORROW, *Treasurer.*
LEON TROUSDALE, *State Supt. Public Instruction.*
W. R. HAMBY, *Adjutant General.*
J. B. KILLEBREW, *Comr. of Agr. Statistics and Mines.*
JAMES M. SAFFORD, *State Geologist.*
J. BERRIEN LINDSLEY, *Sec'y State Board of Education.*
E. KIRBY SMITH, *Chancellor University of Nashville.*
ROBT. A. YOUNG, *Sec. Bd. Tr. Vanderbilt University.*
MORTON B. HOWELL, *Mayor of Nashville.*
E. W. COLE, *Pres. N. C. & St. Louis Railway.*
J. G. M. RAMSEY, *M. D., Pres. Tenn. His. Soc.*

To F. W. PUTNAM, *Secretary A. A. A. S.*

INTERNATIONAL EXHIBITION, PHILADELPHIA.

CENTENNIAL BOARD OF FINANCE,
PHILADELPHIA, JULY 22, 1875.

PROF. J. E. HILGARD,

President Amer. Asso. Adv. of Sci., Washington, D. C.

MY DEAR SIR:—Aubrey H. Smith, Esq., called on us yesterday on behalf of Professors LeConte, Cope and himself to say that your Society will meet at Detroit, Michigan, on the 11th of August next, and to sug-

gest that this city should be selected as the place for holding the annual meeting of 1876.

In this suggestion we most heartily concur, and hope that such a resolution will be adopted. We shall cordially welcome you, and aid, as far as may be in our power, to make the visit agreeable to your members and to afford the Society accommodations for holding its meetings and giving effect to its deliberations. We hope that during our Exhibition we shall have representative bodies in attendance who will by their meetings, discussions and publications, illustrate the progress of the World in the last century in all the departments of Education, Science, Art and Manufactures, so as to make our Centennial a permanent land mark in the World's history.

We have no doubt that as our several scientific and literary bodies hold their autumnal meetings, they will pass resolutions assuring your Society of a hearty welcome to this city, and making such arrangements for its accommodation as the importance of the occasion will demand.

I am, respectfully and truly yours,

FRED. FRALEY, *Sec.*

PHILADELPHIA, AUG. 4, 1875.

PROF. F. W. PUTNAM,

Permanent Secretary of the A. A. A. S.

DEAR SIR:—Please find enclosed a resolution of the Academy of Natural Sciences of this city, extending an invitation to the Am. Asso. Adv. Science to hold its next annual meeting in Philadelphia.

Yours very truly,

E. D. COPE,

Corresp. Secr. Acad. Nat. Sci. Phila.

ACADEMY OF NATURAL SCIENCES,
PHILADELPHIA, JULY 29, 1875.

EDW. D. COPE,

Corresponding Sec. A. N. S. Phila.

SIR:—At the meeting of the Academy held July 27, it was unanimously

RESOLVED,—That the Academy of Natural Sciences of Philadelphia, cordially invite the American Association for the Advancement of Science to meet in Philadelphia in 1876.

Will you please notify the Secretary of the Association of this action on the part of the Academy.

Yours truly,

EDWARD J. NOLAN,

Rec. Sec. A. N. S. Phila.

BUFFALO SOCIETY OF NATURAL SCIENCES.

At the regular meeting of this Society held July 9, 1875, the President, Hon. George W. Clinton, offered the following:

WHEREAS, This Society is confident that the session in this city, in 1876, of the American Association for the Advancement of Science, would be even more productive than that of 1866, of pleasure to our citizens, and of benefit to science. Therefore

RESOLVED, That this Society do most respectfully request the Association to designate Buffalo as the place for its meeting next year.

I hereby certify that the above is a true copy of Resolution passed by the Society July 9th, 1875.

PASCAL P. BEALES,
Recording Secretary.

AT A MEETING OF THE EXECUTIVE COMMITTEE OF THE YOUNG MEN'S ASSOCIATION OF THE CITY OF BUFFALO, HELD ON THE 14TH DAY OF JULY, 1875.

Upon motion the following resolution was unanimously adopted:

RESOLVED, That this Association most cordially unites in requesting the American Association for the Advancement of Science to select our City as the place of its meeting for the ensuing year; and it hereby pledges its best efforts to ensure an agreeable session for all concerned.

RESOLVED, That the Corresponding Secretary cause these resolutions to be engrossed and forwarded to the Association for presentation at its approaching meeting.

FRANKLIN D. LOCKE,
President.

IN COMMON COUNCIL,
BUFFALO, JULY 19, 1875.

COMMUNICATION FROM HIS HONOR THE MAYOR:

The Buffalo Society of Natural Sciences having resolved to request the American Association for the Advancement of Science to hold its annual sessions in this City next year.

I recommend that the Council unite in the invitation.

Respectfully submitted,
[Signed] L. P. DAYTON, *Mayor.*

Received and Filed.

Whereupon Alderman Zink offered the following resolution and moved its adoption: —

The Buffalo Society of Natural Sciences having resolved to request the American Association for the Advancement of Science to hold its session for 1876 in this city, now therefore;

RESOLVED, That the proposed action of the society is cordially approved, and that the Council will, so far as it may, coöperate with the Society, and with all our good citizens, in making the session of 1876, if held here, pleasant to the members of the Association for the Advancement of Science, and promotion of its objects.

Adopted.

I hereby certify that the above is a true copy of a communication from His Honor, the Mayor, submitted to the Common Council, July 19, 1875, and that the resolution following it was duly adopted.

R. D. FORD,
City Clerk.

BUFFALO, JULY 27, 1875.

BUFFALO BOARD OF TRADE,
BUFFALO, AUG. 13, 1875.

AUGUSTUS R. GROTE, ESQ.,
Detroit, Mich.

DEAR SIR:—At a meeting of the members of the Buffalo Board of Trade held this morning, Cyrus Clarke, Esq., President, in the chair, the following preamble and resolution was offered by Alonzo Richmond, Esq., and unanimously adopted:—

WHEREAS, We notice that the Society of Natural Sciences of our city has resolved to invite the "American Association for the Advancement of Science" to hold its next annual meeting at Buffalo in 1876, therefore be it

Resolved, That we, as a Board of Trade, cordially coöperate in this invitation, and shall be pleased to unite in making the session of 1876 a most agreeable one to every attendant upon the "Association."

Resolved, That the Secretary of this Board forward a copy of this preamble and resolution to Mr. Grote, Secretary of our Society of Natural Sciences, who is now at Detroit, attending the annual session of said Association.

Yours truly,
WILLIAM THURSTONE, *Secretary.*

The General Session then adjourned to meet in sections.

The Fourth Day's session was held in the Opera House commencing at 10 o'clock, A. M.

Four persons were recommended to membership by the Standing Committee and elected, and the session then adjourned to meet in sections.

In Section A., Professor T. C. MENDENHALL was chosen Secretary in place of Prof. LANGLEY, who was obliged to leave.

The afternoon was devoted to an excursion on the River.

The Fifth Day's session was held on Monday, in the Opera House, commencing at 10 A. M.

The General Secretary read the names of nine persons, recommended to membership by the Standing Committee, and they were elected.

He also announced that the Nominating Committee recommended the Association to meet next year in Buffalo, upon the 23d of August, and read a list of officers nominated for the next meeting by the same committee.

On the recommendation of the Standing Committee the following preamble and resolution were passed:—

Whereas, The Smithsonian Institution and the Indian Bureaus are now forming a large collection illustrative of the archæology and ethnology of North America, which will constitute a department of the United States Centennial Exhibition at Philadelphia.

Resolved, That the American Association for the Advancement of Science invite the International Congress of Prehistoric Archæologists to hold a meeting, in the year 1876, in the United States, at some locality which may be hereafter designated, and at such time as will not interfere with the meeting of this or of other simillar Scientific Associations.

On behalf of President BARNARD, Prof. H. A. NEWTON read a report of the COMMITTEE ON WEIGHTS AND MEASURES. [The report is printed in part first, p. 19.]

The report of the Committee was accepted and adopted and the Committee continued.

Resolutions proposed by this Committee and recommended by the Standing Committee were then adopted. [See p. 24.]

The COMMITTEE TO MEMORIALIZE THE LEGISLATURE OF NEW YORK FOR A NEW SURVEY OF NIAGARA FALLS, made no report. The Committee was continued and requested to report in writing at the next meeting of the Association.

The COMMITTEE TO REPORT ON THE BEST METHOD OF ORGANIZING AND CONDUCTING STATE GEOLOGICAL SURVEYS had no report to offer and was discharged.

The COMMITTEE TO MEMORIALIZE CONGRESS IN RELATION TO A GEOLOGICAL MAP OF THE UNITED STATES made a verbal statement through Prof. A. WINCHELL. The statement was received and the Committee was discharged.

The COMMITTEE ON THE ELIZABETH THOMPSON DONATION, having made its report at the previous session, the report was accepted, the thanks of the Association voted for the efficiency with which it had completed its work, and the Committee was discharged.

The COMMITTEE TO REPORT ON THE PRINCIPLES OF NOMENCLATURE made a verbal report of progress through Dr. J. L. LECONTE, who hoped that a complete report might be prepared by another year. The report was accepted and the Committee continued.

The COMMITTEE TO MEMORIALIZE CONGRESS AND STATE LEGISLATURES REGARDING THE CULTIVATION OF TIMBER AND THE PRESERVATION OF

FORESTS made a verbal report through Mr. F. B. HOUGH. The Report was accepted and the Committee continued.

Mr. W. H. H. RUSSELL offered a resolution appointing a Committee to prepare a list of the libraries and scientific associations of the country. Referred to the Standing Committee.

The Association then adjourned to meet in Sections.

Sect. A and the Subsection of Chemistry completed the reading of papers on Monday, and adjourned. The Subsection of Chemistry, first electing Prof. G. F. BARKER, of Philadelphia, as Chairman for the ensuing year, passed a resolution requesting the Chairman to prepare an address for the opening session.

The Sixth and last Day's session commenced at 10 A. M., at the Opera House.

Upon the recommendation and nomination of the Standing Committee, nine persons were chosen members, and forty-three members were chosen fellows of the Association.

The Association then proceeded to the election of officers for the ensuing year, and the following gentlemen were chosen:—

President, WILLIAM B. ROGERS, of Boston.
Vice President, Section A., CHARLES A. YOUNG, of Hanover.
Vice President, Section B., EDWARD S. MORSE, of Salem.
General Secretary, THOMAS C. MENDENHALL, of Columbus.
Secretary of Section A., ARTHUR W. WRIGHT, of New Haven.
Secretary of Section B., ALBERT H. TUTTLE, of Columbus.
Treasurer, THOMAS T. BOUVÉ, of Boston.

The Association next approved the recommendation of the Standing Committee to accept the invitations to hold its next meeting at Buffalo, commencing August 23, 1876.

The General Secretary announced that the Standing Committee recommended the Association not to pass the resolution offered by Mr. Russell at the last session, and this recommendation was approved.

On motion of Prof. BARKER, the thanks of the Association were voted to the State, City and other authorities inviting the Association to meet next year at Nashville. The Secretary was directed to transmit these thanks to the proper authorities, with the assurance that the Association would desire to hold the invitations open for acceptance at a future time.

The General Session was then adjourned.

Section B met during the day in subsections only. The officers of the Section held the same position in the Subsection of Biology, Prof. E. D. COPE having been chosen Chairman of the Section on the departure of Vice President DAWSON.

In the Subsection of Geology, Prof. A. WINCHELL was called to the chair, and Mr. C. G. WHEELER chosen Secretary. Both subsections completed the reading of their papers in the afternoon session.

By consent of Section B, a subsection was organized to consider the advisability of forming a Permanent Subsection of Anthropology. Hon. L. H. MORGAN was elected Chairman, and Mr. F. W. PUTNAM, Secretary. The question was decided affirmatively, and Hon. L. H. MORGAN of Rochester, was elected as Chairman for the ensuing year, and Prof. E. T. Cox, Dr. N. TOWNSEND, Col. CHAS. WHITTLESEY, and Messrs. CHARLES RAU and F. W. PUTNAM, were chosen a Committee to invite persons interested in the work of the subsection to attend the meeting next year.

A closing general Session was held the same evening in the Circuit Court Room, City Hall, at which four papers were read, two of them by title and two by their authors, after which the following votes of thanks, were passed by the Association:—

Offered by Prof. E. D. COPE:

Resolved, That the thanks of the Association are due to the members of the Local Committee for their attention to the interests of the members of the Association in procuring for them many essential facilities, and especially to Messrs. Woolfenden, Stearns, Holmes, Muir, Andrews, and Sill, as having contributed to the success of the Detroit meeting.

Offered by Mr. F. W. PUTNAM:

Resolved, That the members of the Association are deeply indebted to the Citizens of Detroit, and especially to the authorities in charge, for the use of the several rooms in the City Hall building, which have been so cordially placed at the disposal of the Association, and have proved so convenient for its present meeting. Also to the members of the Local Committee for the use of the Opera House in which many of the sessions have been held, and to the several officers of the city who have, at great inconvenience to themselves, allowed their offices to be used for the purposes of the Association.

Offered by Mr. E. B. ELLIOTT:

Resolved, That the cordial thanks of the Association be tendered to the Detroit Scientific Association for the very important services which it has rendered to the members of this Association during the session now closing, and especially for the generous reception and entertainment given to them at its new and beautiful rooms on Wednesday last.

Offered by Prof. E. S. MORSE:

Resolved, That the thanks of the Association be presented to Mr. and Mrs. E. A. Brush, and to his excellency Governor J. J. Bagley, for the large hospitality generously extended to all its members.

Offered by Prof. F. W. CLARKE:

Resolved, That the thanks of the Association are due to Mr. and Mrs. A. W. Leggett for the kind reception tendered by them to its members; and for the pleasant entertainment provided at their residence.

Offered by Prof. E. T. COX:

Resolved, That the thanks of this Association are hereby tendered to the Excursion Committee, and especially to Messrs. W. G. Thompson, G. W. Bissell and J. W. Thompson, for the success which attended their efforts in providing us with excursions of scientific and social characters.

Offered by Prof. E. T. Cox:

Resolved, That the thanks of this Association be extended to the Commandant of Fort Wayne, and through him to the Band of the 22d Regiment of Infantry, U. S. A., which volunteered its services during Saturday's excursion.

Offered by Mr. J. D. Warner:

Resolved, That the thanks of the Association be tendered to Hon. H. P. Baldwin for his courtesy in opening his valuable art collection for inspection.

Offered by Mr. G. M. Wilber:

Resolved, That a vote of thanks be given to the Detroit Fire Commissioners, to the officers of the House of Correction, to Messrs. E. B. Smith & Co., and the Detroit Young Men's Society for their kind invitations to visit their several places, and for the generous hospitality extended to the members of the Association.

Offered by Rev. J. G. Morris:

Resolved, That the thanks of the Association are due and are hereby tendered to the proprietors of the following establishments for their courteous invitations to visit them and inspect their various processes:— Wyandotte Silver Smelting Works, Detroit and Lake Superior Copper Smelting Co., Detroit and Lake Superior Iron Co., Detroit Gas Light Co., Detroit Locomotive Works, Detroit Stove Works.

Offered by Rev. J. G. Morris:

Resolved, That thanks are due to Mr. N. W. Clarke for his invitation to visit his Fish Breeding Establishment at Northville.

Offered by Mr. J. D. Warner:

Resolved, That the thanks of the Association are due to Mr. J. M. Maxwell, proprietor of the Biddle House, for earnest endeavors to please and accommodate the members, and also for the generous offer of rooms for committees of the Association.

Offered by Prof. G. F. Barker:

Resolved, That the thanks of the Association be tendered to the Central and Pacific Lake Co., for the facilities which they have extended to its members to visit Duluth and Lake Superior.

Offered by Mr. W. H. H. Russell:

Resolved, That the thanks of the Association are hereby extended to the press of Detroit, its faithful representatives, and the other representatives of the press from abroad, for the full, satisfactory, able and generous reports given of the proceedings of this meeting, and that a copy of the printed proceedings of the Detroit meeting be furnished by the Permanent Secretary to each paper represented.

Offered by W. H. H. Russell:

Resolved, That the thanks of the Association are hereby extended to the Academy of Sciences of Philadelphia, and the Centennial Board of Finance of the International Exhibition of 1876, for the invitations extended to the Association to hold its next meeting in Philadelphia.

There being no further business, President HILGARD addressed the Association as follows:—

LADIES AND GENTLEMEN: Before pronouncing the final adjournment of the Detroit Meeting of the American Association for the Advancement of Science, I will avail myself of the privilege of the chair to make some remarks in review of the session we have just completed. We have all of us observed that in point of the number of members in attendance, the meeting has fallen somewhat below the average, and this for reasons to which I will presently advert; but in point of the quality of the communications received, and the scientific standing of those in attendance, the meeting must be pronounced an unqualified success.

Besides our esteemed colleague, the President of the past year, who has given us so interesting and profound an address, four of our past presidents have been in attendance and have made important communications.

The new feature of our constitution which requires each Vice President, as chairman of a Section, to make an address, has been productive of admirable results, and the communications from members generally have comprised new and weighty matter, giving evidence of great mental activity during the past year. The volume of the proceedings of the Detroit meeting will not be inferior in value to any of its predecessors, and will excel many in quality if not in bulk.

As to the number of members in attendance, it must be born in mind that many of our colleagues are prevented by the *angustæ res domi* from incurring the expense of attending a meeting held at a great distance from their homes; the votaries of science in this country, being for the most part hardworked and ill-paid professors in colleges. There are, moreover, at this time special preoccupations which prevent some of our most valued members from being with us. Our venerable Nestor, Professor Henry, has written us words of sympathy, and explains his absence by his being engaged in making extended experiments on sound, in relation to fog-signals. These experiments he is conducting as chairman of the Light House Board, aided by a staff of officers and two steamers, and it is of course impossible for him to interrupt this work. Similarly the U. S. Fish Commission, which necessarily pursues its researches in summer, withdraws from us the presence of numerous naturalists. The summer schools of science recently established, several geological state surveys, and the geological and geographical surveys of the territories, keep away from our meetings many members who formerly would have found time to attend them. They are, however, all gathering a wealth of new material, and science is clearly the gainer by this state of things, however much we may regret the loss of their friendly presence.

So much for the scientific aspect of the meeting which is now drawing to its close. Its social aspect is equally satisfactory, having been marked by great harmony and cordiality among the members. Views of extreme divergence have been discussed with dispassionate courtesy, and the best feeling has prevailed throughout. Under our new rules, which give

larger powers to the Standing Committee, the formal business of the session, which before encroached so largely upon our time, has been dispatched with ease, and at future sessions, when only one election for fellowships will require to be held, the gain will be still more apparent.

How sensible the members of the Association are of the hearty welcome they have received from the Local Committee, from the Scientific Society of Detroit, and from the leading men of this beautiful and prosperous city, has been so fully and feelingly expressed in their votes of thanks and the utterances which accompanied them, as to leave nothing for me but to say that I most heartily join in the sentiments expressed, and in now closing this session, to bid our Detroit friends an affectionate farewell.

Wm. P. Wells, Esq., on behalf of the citizens of Detroit, made a brief response in which he eloquently assured the members of the Association how fully the citizens of Detroit appreciated the value of the meeting to them, and expressed the hope that it would not be many years before the city would again welcome the Association.

The President then declared the Association adjourned to meet at Buffalo, N. Y., August 23, 1876.

SAMUEL H. SCUDDER,
General Secretary.

REPORT OF THE PERMANENT SECRETARY.

THE following cash account embraces the period from August 8, 1874, to August 4, 1875, including the Hartford Meeting and closing just prior to that of Detroit. It will be noticed that no extraordinary expenses were incurred during the year, and that those of publication, owing to the smaller size of the Hartford volume than its predecessor, and the non-appropriation for engraving, were considerably less than for the previous year. The other current expenses were also reduced, so that the income for the year has been sufficient to reduce the outstanding debt of the Association to $137.25, while at the same time $182.00, received from the commutation of assessments of Life Members, has been placed as a nucleus for a fund for the encouragement of original research in accordance with the provisions of the new Constitution of the Association.

The general work at the office of the Permanent Secretary is annually increasing, and now requires the special and constant attention of an Assistant, who has been employed at the expense of the Secretary during the year.

The Treasurer has reported that the permanent funds in his charge amounted, on November 30, 1874, with accrued interest, to $1,652.81.

The account of the receipts and expenditures of the Thompson Fund is herewith annexed.

F. W. PUTNAM,
Permanent Secretary.

Salem, August 4, 1875.

STATEMENT OF THOMPSON FUND ACCOUNT.

Oct. 3, 1873.	Received from Mrs. Elizabeth Thompson, cash	$500 00
July 2, 1874.	" " " " " "	500 00
Aug. 1, 1875.	" interest on above "	93 33
Aug. 2, 1875.	" advanced by Salem Press	36 76
		$1,130 09

EXPENSES OF PRINTING MR. SCUDDER'S MEMOIR ON FOSSIL BUTTERFLIES, 991 COPIES, 4TO., AS FOLLOWS:

Dec. 10, 1874.	Paid for photographing on wood	$12 00
Jan. 14, 1875.	" " freight on box to Paris	7 38
Jan. 14, "	" " wood	1 50
Jan. 22, "	" " engraving on wood	54 50
Feb. 3, "	" Mr. Scudder, sundry expenses	23 65
Feb. 10, "	" for engraving and printing plates	161 07
June 26, "	" " duty on plates from Paris	42 21
June 26, "	" " express charges, Custom charges, etc.	20 25
Aug. 2, "	" " postage on proofs	1 11
" " "	" " composition	312 22
" " "	" " extra corrections (88 h.)	44 00
" " "	" " 32 reams and 16 quires of paper	287 00
" " "	" " extra paper for 10 copies	4 50
" " "	" " press work (30 forms)	120 00
" " "	" " covers and binding	38 70
		$1,130 09

F. W. PUTNAM,
For the Committee on the Thompson Fund.

Salem, Aug. 4, 1875.

CASH ACCOUNT OF THE PERMANENT SECRETARY.

American Association in Account with F. W. PUTNAM.

1874–75, *Dr.*		1874–5, *Cr.*	
To Expenses of the Hartford Meeting	$ 104 98	By Assessments previous to 23d Meeting,	$ 337 00
Printing and Binding 976 copies Hartford vol.,	1,198 68	Assessments for 23d Meeting (Hartford),	1,600 00
Printing and Binding 300 copies President's Address	22 25	Assessments for 24th Meeting (Detroit),	348 00
Wrapping Hartford vol. for Distribution,	9 00	Entrance fees for 23d Meeting (Hartford),	525 00
Electrotyping pages in Hartford vol.,	21 40	Fellowship fees,	442 00
Engraving for Hartford vol.,	4 00	Life Membership commutations,	183 00
Printing Circulars, Blanks, Tickets, Envelopes, etc.,	151 10	Volumes sold and binding,	315 38
W. W. Wheildon, Expenses Com. Act of Incorporation,	6 50	President's Address sold,	1 89
Fellowship Book $8.00, Binding Records $1.25,	9 25	Premium on gold, postage, and express,	78
Postage $197.42, Express $39.80, Telegrams $2.19,	239 41	Donation from George B. Emerson,	25 00
Rent of Office $100.00, Office Incidentals $6.09,	106 09	Balance due Permanent Secretary,	137 25
Binding Proceedings for sale,	50 70		
Salary of Permanent Secretary, 1875,	1,000 00		
Permanent Secretary, balance due Aug., 1874,	806 94		
Life Membership Fund,	183 00		
	$3,914 30		$3,914 30

I have examined the above account and certify that the same is correctly cast and properly vouched.

H. WHEATLAND, *Auditor*.

SALEM, August 6, 1875.

STOCK ACCOUNT OF THE PERMANENT SECRETARY.

DURING the past month it became necessary to remove the office of the Association from the room in the Museum building, in Salem, to new quarters. A much larger, lighter, and in every way superior room for the purpose, was found over the Mercantile Bank, in the "Bank building" No. 7 Central Street, Salem, for which the same rent is to be paid as heretofore.

In making the change it was deemed advisable to put a large number of the stock of back volumes in boxes, and opportunity was thus given to make a careful recount of all the stock on hand. Forty-five copies of volumes (fortunately of those of which there are the largest number of copies) which had become discolored and decayed from dampness in their place of storage many years ago, were condemned. It was also found that the error in former counts of the copies of volumes on hand was two hundred and forty-three, making it necessary to deduct two hundred and eighty-eight copies from the sum total carried over as on hand at the last account.

Of the volumes now on hand, forty full sets, of Volumes 1 to 23 inclusive, are in boxes of five sets each, and forty-one other boxes of the same size are filled with volumes, and properly labelled; these are stored in the new office and in the attic above. The balance of the volumes are arranged conveniently on shelves in the new office.

The following presents a tabular view of the receipt and distribution of volumes since the account printed in the Hartford volume, and dated March 15, 1875.

Copies of Transactions of the Old Society, and of the 22 Vols. of Proceedings of the Association, on hand from last account,				10,258
Copies of Proceedings Hartford Meeting received from printer, May 1, 1875,				976
				11,234
Distributed to Members,	674 copies of Hartford Vol.,	and	71 of other Vols.,	745
Dist. by vote Stand. Com.,	91 " " "	"	87 " "	178
Sold,	12 " " "	"	124 " "	136
Condemmed,	00 " " "	"	45 " "	45
	777		327	1,104
Leaving on hand to new account,				10,130

The Memoirs, No. 1, of the Association, printed by the donation of Mrs. Thompson, have been partially distributed in accordance with the instructions of the Standing Committee, and the distribution will be continued as information is obtained of the libraries entitled to receive the work.

Copies of Memoirs, No. 1, received from printer August 2, 1875,	991
" " " " distributed by direction of Standing Committee	361
" " " " sold,	15
	376
Leaving on hand to new account,	615

The library of the Association is yearly increasing in size. A manuscript catalogue has been prepared of the twelve hundred volumes, parts of volumes and pamphlets now belonging to the library, and as soon as advantage can be taken of the proposed general catalogue of similar publications to be issued by the libraries of Boston, Cambridge and Salem, a printed catalogue will be furnished to members in order to give them the benefits which suggested the formation of the Association Library.

F. W. PUTNAM,
Permanent Secretary.

Salem, June 2, 1876.

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